DOCTOR OF PHILOSOPHY

Environmental Challenges and Linkages to Smallholder Agriculture in the Nigerian drylands: Implications for Food Security

Jellason, Patrick N.

Award date:
2018

Awarding institution:
Coventry University
Royal Agricultural University

Environmental Challenges and Linkages to Smallholder Agriculture in the Nigerian drylands: Implications for Food Security

By

N. P. Jellason

July 2018

Coventry University

in association with the

Royal Agricultural University

A thesis submitted in partial fulfilment of the University's requirements for Degree of Doctor of Philosophy

ROYAL AGRICULTURAL UNIVERSITY
CIRENCESTER

Ethical Approval Certificate

The details provided in the 'Ethics Approval Form' by Patrick Jellason was approved by the Research Committee before commencement of the research. The document is attached to this thesis.

This is to certify that the research undertaken and completed by the candidate and reported in this thesis has satisfied the requirements of the University of Coventry and Royal Agricultural University's Ethical Principles and Procedures for Teaching and Research and the Code on Good Research Practice.

Professor Meriel Moore-Colyer
Director of Research
Royal Agricultural University

Royal Agricultural University, Cirencester, Gloucestershire, England GL7 6JS
Telephone: +44(0)1285 652531 · Admissions: +44(0)1285 889912 · Facsimile: +44(0)1285 650219 · Website: www.rau.ac.uk

ABSTRACT

Environmental Challenges and Linkages to Smallholder Agriculture in the Nigerian drylands: Implications for Food Security

Dryland smallholders of Nigeria have successfully lived with environmental challenges and past experiences will help prepare them for future climatic variations. However, predicted changes will exceed collective experiences, and these communities are thus more likely to be at risk. This work focused on co-developing science-informed Good Agricultural Practices (GAPs) with smallholders as mitigative and adaptive solutions for resilience to climate changes.

Mixed methods were employed; including: a Delphi study of GAPs with experts; baseline survey of smallholders' existing practices; in-depth interviews; focus group discussions; pre- and post-participatory training surveys; Theory of Planned Behaviour survey and stakeholder engagement.

Data were collected from a total of 220 respondents in two drylands communities (Kofa and Zango- hotter and drier) in North-West Nigeria. Quantitative data were analysed using descriptive statistics, Principal Component Analysis (PCA), and Multiple Regression. Qualitative data were thematically analysed using Nvivo.

Zango households perceived increased temperatures while Kofa households perceived reduced rainfall and drought as the signs of climatic fluctuations; farmers lacked water and soil fertility management practices important for resilience promotion. The pre- and post-co-learning surveys indicated improved confidence to manage environmental challenges leading to resilience. Attitude towards behaviour and subjective norm were the most important determinants of intention ($p < 0.05$) to adapt to environmental change in Kofa while only attitude was important in Zango. Thus, households were more likely to integrate adaptation into their farming practices when the climate is perceived to be changing.

Extension knowledge gaps exist and a new model of extension was proposed; however, fatalistic belief in God as the cause of climate and environmental change could leave the communities vulnerable.

The original contributions of this thesis include the development of a framework for transitioning vulnerable farmers to be more resilient, and the farmer segmentation model. Further studies are needed to consider detailed exploration of farmer behaviour towards decision-making for adaptation.

DECLARATION

The body of work in this thesis is based on the author’s independent research at the Royal Agricultural University, Cirencester under the supervision of Dr Richard N. Baines and Dr John S. Conway. The author is responsible for the data collection, data analysis, interpretation, model development, theory testing and conclusions reached within this thesis. All support and advice received from colleagues are duly acknowledged. The methodology was subjected to formal ethical review and approved by the Royal Agricultural University ethics committee as part of approving the overall research proposal (RDC1).

Nugun Patrick Jellason

July 2018

DEDICATION

To God the giver of wisdom and foresight and to my parents Honourable Anthony and Mrs. Josephine Jellason for providing the necessary funding to undertake this Ph.D. project, I dedicate this thesis.

ACKNOWLEDGEMENTS

As in the words of Robert Chambers writing on ‘Rural Development: Putting the Last First’, this thesis was like painting a long bridge, getting to one end, the other end needing redoing! However, this process has led to a deeper understanding of how resilience could be enhanced in this era of unpredictability in the climate variables.

Initially, I felt I was being pushed by some invisible hands to embark on the Ph.D journey! Lost in the world of my thoughts and with less confidence. First day of arrival in The RAU morning of 9th January 2015 in the middle of the English winter, lonely on the footpaths from Cirencester town centre to the RAU. I was like is this where I will be spending the next 3 years? There I was on the right wing, first floor of the Frank Garner building in the second to the last office on the left faced with a total stranger who I scantily communicated with in email exchanges before arrival. His first introduction changed my perspective completely on my new home! ‘Hey mate, I am Richard nice to meet you…’ nice to meet you too. I have gone through your proposals and it’s a wonderful project…I will be travelling to South Africa for a project tomorrow so here is a work plan template you can use to develop yours and I will write a mail to 2 other Nigerian students on the PhD to guide you…from today call me Richard we are now colleagues. In the first year, you’ll be learning from me and I expect that you take over the lead and show the way the project should continue. That is, I will start learning from you afterward. Thank you. So, see you when I return’. So, from day one my impression changed, and the real work started. Overall, the experience has been rewarding and as they say, the rest is now history. All through the years, Richard had confidence in my abilities even when I felt incapable of doing certain things. This further bolstered my self-confidence. For the supervisory, moral, financial and business support, I am indeed grateful. To my second advisor-Dr John Conway, words fail me to describe how your critical stance has shaped my thinking and the output from this thesis. Your constant reminder to always ask the ‘why’ question has made all the difference. Thank you so much.

Special thanks to my parents, and siblings-Raphael, Margaret, Elizabeth, Yinalabi, Dorathy, Francis and Dashon for their love, understanding and believe in me.

The overall research project has been made possible through generous financial support from numerous organizations and people: National Biotechnology Development Agency for granting me study leave with pay; The Royal Agricultural University for tuition discount in my third year and international conference sponsorship; Hon. John Kizito Bonzena and Senator Sani Abubakar Danladi for their financial support in the first year of my research.

Many people and organizations have assisted in one way or the other to make this project a success. Centre for Drylands Agriculture-Kano Nigeria for providing links to the study communities. The study participants and community leaders for their patience throughout the period of the research. Patrick Kefas, Benedict Emmanuel and Habila Nehemiah for support with fieldwork. Drs. Ambituuni, Jake, Ogbaga for always providing useful guide, thanks very much indeed! Thank you, Dr. Jummai Adamu my Director for the initial nudge.

I also owe special thanks to the Library staff: Theano, Peter, and Emma, thanks for your help. A big thank you also go to the Registry staff for always having to bear with my queries and demands. Thank you, catering staff-especially Mandy, Mike, Andy, Dee for supporting me. Special thanks to Karen Czapiewski, Karen Rial-Lovera and Michelle Tutty for writing tips, presentation practice and proof reading. I also thank Professor Ali Parsa and Steve Thomas for advice and support.

Many colleagues and friends made the research years bearable. For ideas, moral boost, and even some social engagements beyond the call of duty, I appreciate Frs. Isidore, Tumba, Chifu, Muke, and Atsue. I thank Sebastian Ugbaje for producing my maps, Donwell, Sally Curzon, Kemi, Alice, Ibrahim, Adeola, Gabriel, Patrick, Engha, Eko, Emmanuel, Ignatius, Joy, Yunusa, Bala, Joe, Zia, Sesugh, Eric, Sam Kamai, Dan, Alh. Sale, Uncle Vincent and others too numerous to mention.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

APPENDICES

ACRONYMS

ADPs	Agricultural Development Programmes
AERLS	Agricultural Extension Research and Liaison Services
AEZs	Agro-Ecological Zones
AFOLU	Agriculture, Forestry and Other Land Uses
AGRA	Alliance for a Green Revolution in Africa
APP	Agricultural Promotion Policy
ARCN	Agricultural Research Network
ATA	Agricultural Transformation Agenda
BMPs	Best Management Practices
BNRCC	Building Nigeria’s Response on Climate Change

BUK	Bayero University Kano
C	Carbon
CA	Conservation Agriculture
CAADP	Comprehensive African Agricultural Development Programme
CBD	Convention on Biological Diversity
CBN	Central Bank of Nigeria
CDA	Centre for Drylands Agriculture
CGIAR	Consultative Group for International Agricultural Research
CO_2	Carbon dioxide
CSA	Climate Smart Agriculture
CT	Conservation Tillage
DfID	Department for International Development
DFRRI	Department of Food Road & Rural Infrastructure
DLDD	Desertification Land Degradation and Drought
ECN	Energy Commission of Nigeria
EU	European Union
FAO	Food and Agricultural Organization
FCT	Federal Capital Territory
FEPA	Federal Environmental Protection Agency
FFS	Farmer field schools
FGD	Focus Group Discussion
FMARD	Federal Ministry of Agriculture & Rural Development
FMEEN/UNIMAID	Federal Ministry of Environment/University of Maiduguri
FRN	Federal Republic of Nigeria
GAPs	Good agricultural practices
GCMS	Gas Chromatography Mass Spectrometer
GDP	Gross Domestic Product
GESS	Growth Enhancement Support Scheme
GGWP	Great Green Wall Programme
GHGs	Greenhouse gases
GM	Genetically Modified
Ha	Hectares
HND	Higher National Diploma
HPLC	High Performance Liquid Chromatography
IBM	International Business Machines
IBRD	International Bank for Reconstruction and Development
ICARDA	International Centre for Agricultural Research in Dry Areas
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
ICT	Information and Communication Technology
ID	Identity
IFAD	International Fund for Agricultural Development
ILRI	International Livestock Research Institute
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union of Conservation of Nature
IWMI	International Water Management Institute
KCSZ	Kano Closed-Settled Zone
KSACDP	Katsina State Agricultural and Community Development Project
KTARDA	Katsina State Agricultural and Rural Development Authority

LEEDS	Local Economic Empowerment & Development Strategies
LRS	Length of Rainy Season
LSMS	Living Standard Measurement Study
MEA	Millennium Ecosystem Assessment
Mm	Millimetres
MOU	Memorandum of Understanding
NA	Not applicable
NACB	Nigerian Agricultural & Cooperative Bank
NAP	National Adaptation Programme
NAPRI	National Animal Production Research Institute
NARF	Nigerian National Agricultural Resilience Framework
NARS	National Agricultural Research System
NBS	National Bureau of Statistics
NEAZDP	Northeast Arid Zone Development Programme
NEEDS	National Economic Empowerment & Development Strategies
NEPAD	New Partnership for Africa's Development
NESREA	National Environmental Standards and Regulations Enforcement agency
NGN	Nigerian Naira
NiMet	Nigerian Meteorological Agency
NIRSAL	Nigerian Incentive-Based Risk Sharing System for Agricultural Lending
NSPP	Nigerian Society for Plant Protection
NSPFS	National Special Programme for Food Security
N_2O	Nitrogen dioxide
ODA	Official Development Assistance
PACD	Plan of Action to Combat Desertification
PBC	Perceived Behavioural Control
PCA	Principal Component Analysis
PET	Potential Evapotranspiration
Ph.D	Doctor of Philosophy
p.p.m	Part per million
PRA	Participatory Rural Appraisal
PVC	Polyvinyl Chloride
QL	Qualitative
QN	Quantitative
RBDAs	River Basin Development Authorities
REDD	Reduced Emissions from Deforestation and Forest Degradation
REDD+	Reduced Emissions from Deforestation and Forest Degradation plus
RTEP	Root and Tuber Expansion Programme
R&D	Research & Development
SD	Standard Deviation
SDGs	Sustainable Development Goals
SEPP	Sokoto State Environmental Protection Programme
SES	Socio-ecological systems
SI	Sustainable Intensification
SLM	Sustainable Land Management
SPSS	Statistical Packages for the Social Sciences
SSA	Sub-Saharan Africa

T	Tonne
TPB	Theory of Planned Behaviour
TV	Television
T & V	Training and visits
UK	United Kingdom
UN	United Nations
UNCBD	United Nations Convention on Biodiversity
UNCCD	United Nations Convention to Combat Desertification
UNCOD	United Nations Conference on Desertification
UNCTAD	United Nations Conference on Trade and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
US$	United States Dollar
VIP	Ventilated Improved Pit
V-RTPM	Vulnerability-Resilience Transition Pathway Model
WCED	World Commission on Environment and Development
WH	Water Harvesting
&	And
£	Great British Pound

CHAPTER ONE

1.0. Background and context

Mankind's ability to feed itself in the future is threatened by increasing pressures on natural resources, growing inequality, poverty and climate change impacts. Although much progress towards reducing global hunger has been recorded in the past 30 years, "expanding food production and economic growth have often come at a heavy cost to the natural environment," (FAO, 2017a). At continental level, Africa's agriculture has recorded considerable progress across all regions as net output is said to have trebled in the last 50 years with North and West Africa being the regions with the most growth recorded. Despite this, increasing population growth; changes in diet to consumption of more fruits, vegetables, milk, meat and processed food; climate change effects; and environmental degradation have remained significant threats to African agriculture (Foresight, 2011; ICARDA, 2015) especially in terms of losses in production (McCusker and Carr, 2006). The sector is also faced with the constraint of minimising or reversing greenhouse gas emissions associated with domestic livestock and fertiliser use. In particular, inorganic and organic fertilizer use to support increased food production per unit area and emissions from livestock rearing mainly through '*enteric fermentation and manure'* (Foresight, 2011). The FAO (2017a) reported: "climate change will affect every aspect of food production," through increased frequencies of floods, drought and rainfall variability. Despite this, the agricultural sector in sub-Saharan Africa (SSA) remains the major source of livelihoods providing about 65% of the population with full-time jobs; and is also responsible for 50% of all export earnings.

Moreover, the great Sahel drought of 1969 to 1974 further exposed to the world the specific Sahel crisis and since then the conditions faced by rural households in the drylands of SSA have been a subject of environmental research and development (Mortimore, 1998; Mortimore and Adam, 1999; van Vliet *et al.*, 2013). These challenges highlighted are also of critical importance to the food security of Nigeria as about 34 million people inhabit the Nigerian drylands (Ola-Adams and Okali, 2008) with the population predicted to increase significantly. Most of these populations are poor, hungry and depend on the natural environment for their livelihoods thereby further adding pressure on resources and predisposing communities to more risks and uncertainties. It is no coincidence, therefore, that global interest in sustainable development and concerns about climate change have come at a time when poor smallholder farmers of northern Nigeria's drylands are faced with the twin challenges of feeding their increasing population and ensuring environmental sustainability against a backdrop of worsening weather conditions.

Dryland smallholders are at crossroads and the question often asked is 'will these poor and vulnerable farmers indiscriminately exploit the environment to maximize their short-term crop yields to compensate losses from rainfall variability, poor soil fertility and extreme temperatures or will they be more concerned about environmental sustainability and resilience'? As Lal (2013) noted, the stewardship of the environment is only an important concept when the basic needs for food by the poor is met. UNCTAD (2009) asserts however, that innovation could be the solution to improving agricultural productivity and simultaneously enhancing sustainability of the environment. Therefore, this thesis will attempt to strike a balance between the two important development goals of sustainable development and climate change mitigation by exploring opportunities for mitigating greenhouse gases through the adoption of appropriate Good Agricultural Practices (GAPs) that can ensure improved food security through sustainable intensification and that also maintains ecosystem services (Vanlauwe *et al*., 2014). GAPs according to the FAO refer to the application of available knowledge and recommendations for ensuring economic, environmental and social sustainability for farm production and post-production activities which leads to safe food and 'non-food agricultural products' (FAO, 2003). However, in reality GAPs in this context are mainly focussing on environmental parameters not food safety.

Practices such as sustainable intensification may be more resilient in the long term (Vanlauwe *et al*., 2014), however, there is a need for location specific approaches to prevent or mitigate degradation successfully at the farm level by harmonising scientific knowledge with local farmers' individual and collective experiences in designing site specific management strategies (Bindraban *et al*., 2012). In addition to utilising farmer knowledge, such strategies and advice on how to implement good agricultural practices that have empirical evidence of success with smallholder farming will aid this transition through farmer engagement (Burbi *et al.*, 2013). By doing this, the focus will be in achieving the broader development goals of adaptation and mitigation as opposed to the narrow view of increasing productivity as advocated by the former agricultural modernisation advocates (Whitfield, 2016).

1.1. Problem statement

Small scale farmers in sub-Saharan Africa are responsible for producing 90% of food consumed in the region with between 25 and 30% of the GDP in Africa generated from agriculture (Foresight, 2011) compared to the developed countries. In the context of drylands, the IPCC (2007:4) reported that "in the Sahelian region of Africa, warmer and drier conditions have led to a reduced length of growing season with detrimental effects on crops". The report also asserts that by early 2020, around 75 to 250 million people are anticipated to be affected by water stress emanating from climate change (IPCC, 2007). Furthermore, a 2ºC rise in temperature is projected to lead to 5-10% decline in crop yield in Africa (Stern Review, 2006). Despite the abilities of societies to cope, Adger *et al.* (2003) argue that:

'*…some sectors are more sensitive and some groups in society more vulnerable to the risks posed by climate change than others. Yet all societies need to enhance their adaptive capacity to face both present and future climate change[s] outside their experienced coping range.'*

This observation is critical to this study as the projected changes in weather patterns will mean that communities will experience new environmental challenges beyond the scope of their collective experiences and practices.

Technology options are also limited as, only 4 percent of SSA agricultural land is under irrigation (Juma, 2015; Ward *et al.*, 2016) with limited scope for expansion of water resources and agricultural land (FAO, 2017a). As such, most farmers rely on rain-fed agriculture which increases their vulnerability. Also, losses in agricultural yield will potentially lead to a greater proportionate loss in income in a developing country context compared to a developed country (Cline, 2007). Consequently, the end result is poverty which further hinders food access leading to intense suffering.

The Nigerian agricultural sector has performed poorly in recent years with little positive impact on the economy which has been linked with environmental degradation. This has led to shortage of food and reduced export earnings and GDP contribution (Jalloh *et al.*, 2013). If the Nigerian government does not factor climate change adaptation and mitigation measures in its development strategies, the challenges will be further worsened according to Jalloh *et al.* (2013). The drylands of Nigeria that account for a considerable proportion of food supply in the country will be worst hit by these environmental challenges leading to increased poverty, sensitivity to drought and over-reliance on rain-fed systems for their livelihoods. For example, from 1950-2008, intense drought scenarios occurred with higher frequency in the ‘drier northern part of Nigeria’ which lasted 2 or more years than in the humid central or wetter southern parts that enjoy better rainfall (Morris and Cervigni, 2016: 38). This was worst in the north-western part with “severe drought events occurring in more than 30 percent of all years” (Morris and Cervigni, 2016: 38). In Nigeria, as elsewhere there is a wider economic impact from environmental challenges. For example, the doubling of the food commodity prices will lead to high negative effect on the country’s GDP (-7.2). This is the second highest negative effect globally after Benin republic (-8.6) (UNEP, 2016).

Hence, it will be difficult to meet most of the long-term Sustainable Development Goals building on the Millennium Development Goals of reducing poverty and increasing prosperity of the region if the challenges of drylands are not tackled (Cervigni and Morris, 2016). Investment in water and integrated soil conservation technologies that are low cost could support agricultural water management in drylands’ rain-fed systems and would improve resilience of a large population (Ward *et al*., 2016). Moreover, it is important that these farmers are provided with appropriate information and support that is location specific that will mitigate degradation successfully while enhancing food security; if not then these environmental challenges will have effects on productivity of the region (Wiebe, 2003; Bindraban *et al*., 2012); thereby threatening food security in the medium to long-term (Ashton *et al*., 1999; Bindraban *et al*., 2012; Altieri and Nicholls, 2012). Farmers and the agriculture sector per se have been seen to be part of the problem of climate change, but are also part of the solution which offers an opportunity for new technologies for mitigation and adaptation for agricultural entrepreneurs and farmers alike (The Montpellier Panel, 2015). It is also critical to harmonise such technologies with the collective knowledge and experiences of these communities (Burbi *et al.*, 2013).

In the Sudano-Sahelian zone of Nigeria, to successfully adapt to climate change will require a holistic approach to “design and promote planned adaptation measures that fit into local context and also to educate farmers on climate change and appropriate adaptation measures” (Tambo and Abdoulaye, 2013: 375). Also, such an approach should seek to avoid failure in future development projects like those of the past, according to Binns (1995: 3) who stated that:

'future development planning must be based upon a detailed understanding of what is there now and should fully appreciate the intricacies, strengths and weaknesses of indigenous livelihood systems and the aspirations of the people involved'.

This study is important based on the increasing potentials of northern Nigerian drylands in terms of land availability, irrigation opportunities and labour availability in order to supply the additional food needed to feed the increasing population in Nigeria and to reduce the export bills on high-demand crops like wheat and other cereals. Secondly, building resilience to other shocks and drought is necessary as communities and households are currently faced with shocks with no means of responding, hence making them perpetually poor (Cervigni and Morris, 2016). Previous agricultural policies in Nigeria have failed to positively harness these potentials but rather have promoted unsustainable practices such as large-scale dam construction for these drylands that have subsequently led to diminished productivity of agriculture (Ikpi, 1995). This thesis therefore contributes to the search for an alternative means of food production in the drylands of north-western Nigeria amid climate and environmental challenges to enhance resilience and promote food and nutrition security of the country. These alternative means are considered climate smart. The study also has the potential to better inform agricultural policy and implementation through extension activities going forward.

1.2. Overall aim of the research

This study aims to explore how agricultural resilience can be enhanced amid environmental challenges facing small scale farming in sub-Saharan African drylands and to determine how to achieve greater sustainability and food security while exploring opportunities for greenhouse gases mitigation in these drylands using GAPs. By integrating indigenous understanding of farming conditions with scientifically sound and appropriate GAPs, the study relies on two communities in the region. The Zango and Kofa communities in North-Western Nigerian semi-Arid Zone were engaged in this participatory study as cases in point. Resilience in this context, refers to the capacity of socio-ecological systems (Adger, 2006) to persist and sustain function amid disturbance (Gunderson and Holling, 2001). Socio-ecological systems (SES) refer to the mutual interaction between 'societal (human) and ecological (biophysical) subsystems' (Gallopín, 2006).

1.3. Research objectives

To achieve the above aim, this study addressed the following objectives, to;

1. assess the vulnerability conditions of the dryland farmers to environmental challenges and identify opportunities for resilience;

2. examine the extent of use of good agricultural practices by North-Western Nigerian dryland farmers and how they are conditioned by extension, culture and the local economy;

3. examine and evaluate farmer knowledge and understanding of global and local environmental challenges and their attitudes to these challenges;

4. select, set up and test prioritised GAPs based on review of scientific evidence and evaluate with farmers the outcomes of the tested GAPs; and,

5. appraise the barriers for non-adoption and the process of adoption so that lessons learnt can be transferred into more effective extension.

Based on the above, the study will attempt to develop a framework with farmers and other key stakeholders for continuing the development of the GAPs which supports agricultural resilience, sustainability, food security, and poverty reduction as well as contributing to climate change mitigation and adaptation in Nigerian, and sub-Saharan African drylands from both a top down (policy) and a bottom up (farmer) perspective.

1.4. Research strategy

This study is based on Participatory Action Research (PAR) models whereby farmers' experiences on environmental challenges of dryland agriculture are combined with scientific evidence of GAPs in order to assist selected farmers to co-develop specific cropping action plans (Burbi *et al.,* 2013). The participatory action planning was facilitated through the research team in association with local extension agents. Participating farmers were then re-visited after the growing season to assess adoption or not along with reasons for such farmer decisions.

It was envisaged that this top down science-based evidence allied to the bottom up experiences would lead to improved adoption and enhanced extension engagement that will help inform policy developments in the future.

The philosophical approach taken by this study would best be described as pragmatism or a mixed method approach in that the evaluation of environmental parameters and the efficacy of GAPs is based on quantitative and deductive studies while farmer engagement and behaviours relies more heavily on the application of the social sciences and inductive studies. As such, several lines of enquiry were carried out as follows:

a) **Climate-smart agriculture (CSA):** CSA is an agro-ecological approach to farming aimed at achieving short-and-long-term agricultural development priorities in the face of climate change which also helps in achieving other development objectives under an enabling technical, policy and investment conditions (FAO, 2013). As part of this approach, individual practices are often termed GAPs. The literature review focused on the evidence of environmental impacts of farmer practices on dryland agricultural areas and on the attempts to improve performance through public extension. In addition, good agricultural practice guidance for drylands was critically reviewed in terms of the scientific evidence underpinning them and in relation to adopting more climate-smart and agro-ecological farming techniques. This evidence was used to engage extension workers and farmers in their understanding and use of such practices.

b) **Key informants on farmer guidance:** This entailed analysis of the content of existing extension information through face to face interviews with high level stakeholders and field officers on GAPs and their suitability in improving environmental and farmer livelihood conditions. In order to have a wider perspective of their field experiences, key informant interviews with lead extension staff from five different organisations involved with research and extension around the study communities were conducted (i.e the Institute of Agricultural Research, Zaria, Centre for Dryland Agriculture, Kano, and State Government ADPs in (Kano and Katsina States-Nigeria); further interviews with staff at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) were also conducted.

c) **Farmer engagement**: Two case study communities were identified in the arid and semi-arid ecological zones of Nigeria, one with extreme dry conditions and with evidence of food insecurity (Appendix 2a) and the other in a semi dry condition with relatively better food security. The following participatory research steps were carried out with these communities through three visits over two growing seasons:

- The first visit focused on initial community meetings to introduce the researcher and research objectives, to gain permission to work with the community, to gather baseline information on livelihoods of families and assess current practices and extension advice.
- The second visit reported on initial findings and provided information on improved adoption of carefully reviewed GAPs guidelines through focus group training and interviews. Households were then invited based on baseline results to engage in participatory planning for the next growing season based on their own knowledge and the introduced GAPs. This resulted in specific farmer action plan being developed.
- The third visit was used to appraise adoption of co-developed action plans and evaluate the reasons and barriers to non-adoption if not practiced during the growing season.

The research concluded with a final stakeholder meeting in the communities. Furthermore, community meetings were carried out on each visit to inform farmers, the community and extension officers of research objectives, progress and conclusions along with lessons learnt.

d) **Adapted livelihood survey**: Initially, 200 households were targeted i.e. 100 households per community to create a baseline; however, 220 households were eventually captured (120 in Zango and 100 in Kofa communities) due to willingness of farmers to participate. Key themes in the survey included household assets, farm characteristics, income generating activities and enterprises involved in by farming households along with additional questions focusing specifically on dry-land environmental challenges (e.g. soil and water conservation; degraded land restoration and soil fertility improvement techniques) and farmer coping strategies and available guidance.

e) **Selected Farmer and Farmer to Farmer Action Plans**: From the survey 30 lead farmers per community were selected based on PCA findings to work with in developing action plans and guidance to consider. These farmers were also asked to share their action plans with five other farmers as a cluster (lead farmer extension model) (Mogues *et al.,* 2008). Action plans were developed in line with individual farm/farmer requirement on additional best practices to adopt. Farmers were facilitated in these approaches along with extension workers in the community. I encouraged these lead farmers to work with extension officers and to also work with other farmers in the clusters to improve their practices.

1.5. Structure of thesis

This study is structured as follows;

Chapter two explores existing literature and reports on dryland farming around the world with specific focus on sub-Saharan Africa and Nigeria. This includes traditional farming systems, challenges of dryland agriculture, the role of smallholders, research and extension in drylands together with drylands policies and implementation, risk perception and response (adaptation) strategies; the role of indigenous knowledge to resilience enhancement for food security was also examined.

Chapter three focuses on the sustainability of dryland farming in Nigerian drylands and in the context of policies and strategies on protecting the agricultural resource base for food security along with land and water resources management strategies. Innovations in agricultural production were evaluated within the nexus of food security and the environment.

Chapter four introduces the case study area and communities and discusses in more detail the evidence supporting the chosen research strategy and supporting methodologies used for data collection and for the farmer and expert engagement.

Chapter five presents the baseline profiles of livelihood strategies, assets and farming systems. In addition, current extension strategies are described from both farmer and extension officer perspectives as determined by the first field visit. Results of Principal Component Analysis and Theory of Planned Behaviour are presented.

Chapter six describes the results of the Delphi study and stakeholder engagement around GAPs and existing extension strategies and knowledge in the study communities which informed the co-learning activity in chapter seven.

Chapter seven presents result of the co-learning activities, determinants, and barriers to adoption of the introduced GAPs interpretation of results and discussions on findings.

Chapter eight presents result of the vulnerability assessment and the vulnerability-resilience transition pathway model developed as an overall outcome of the research.

Chapter nine presents a summary of the general discussion and key findings, conclusions drawn, lessons learned, policy considerations and opportunities for further studies.

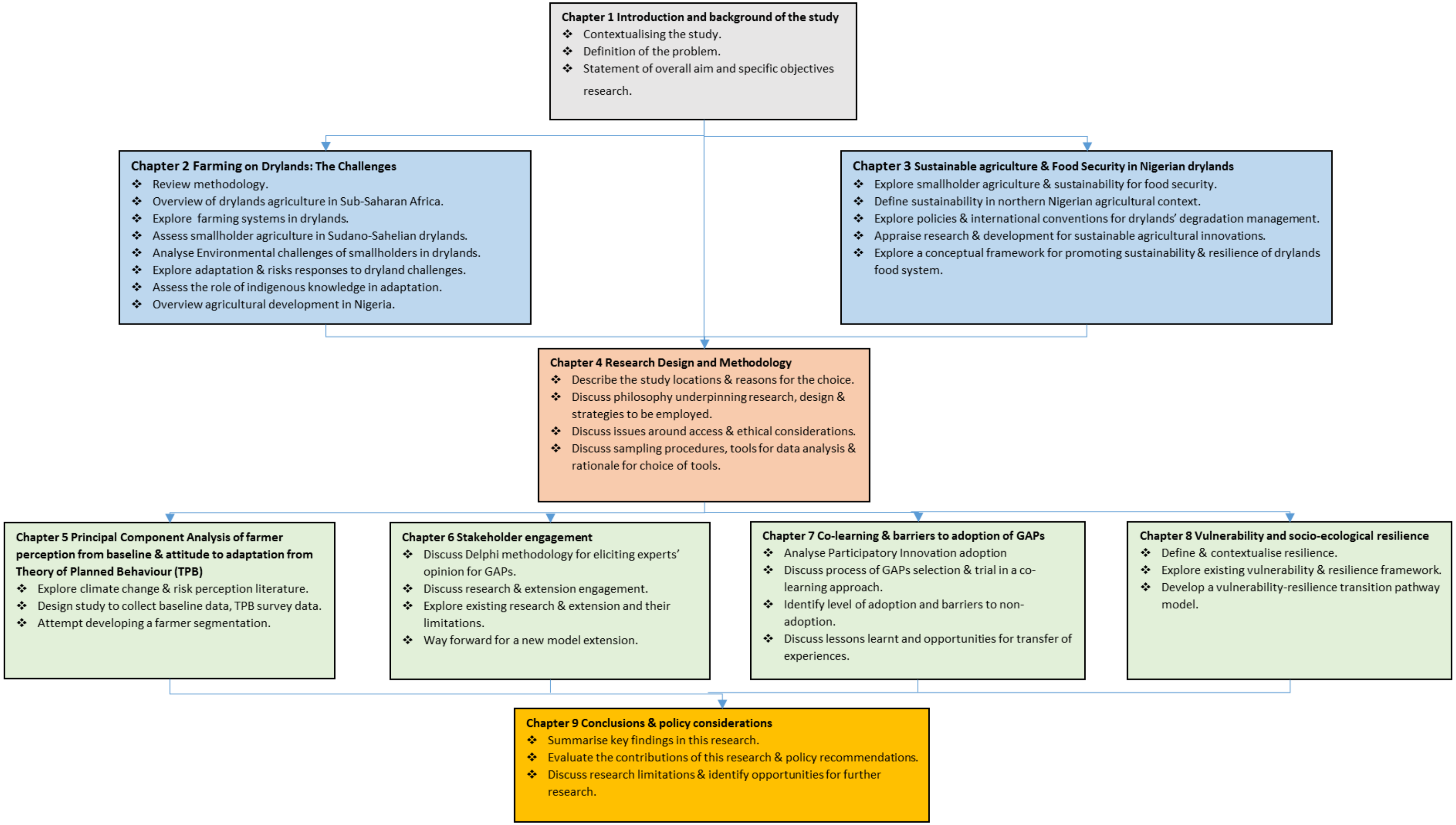


Figure 1.1 The structure of the study.

CHAPTER TWO

Smallholder farming on Drylands: The Challenges

Objectives

The objectives of this chapter are to:

- determine through a review of the literature, the key challenges to drylands agriculture in the Sudano-Sahelian zone of Nigeria in the context of climate change and;
- examine the adequacy of smallholders' current responses to these challenges.

2.0 Introduction

The world population is projected to continue increasing and to peak at about 9 billion people by the year 2050 (UNDESA, 2016). Moreover, promoting food security under a rapid demographic transition and increasing impacts of climate change without causing harm to the environment is one of the biggest paradoxes of this millennium (Godfray *et al.*, 2010; Were *et al.*, 2016). In sub-Saharan Africa (SSA), populations mainly rely on smallholders to feed them, smallholders who ‘cultivate small parcels of, mostly degraded land and have no access to reliable irrigation, affordable inputs, financial credit services, output markets and agricultural information’ (sic) (Were *et al.*, 2016). As climate change intensifies, SSA inhabitants will become increasingly vulnerable to the impact of climate fluctuations (Raju and Wani, 2016) due to poverty (Boko *et al.*, 2007), malnutrition (Were *et al.*, 2016), and reliance on rain-fed agriculture which currently supplies 90 percent of food staples (Van Duivenbooden *et al.*, 2000; Ward *et al.*, 2016).

Due to the availability of some suitable land for agriculture in Africa and some parts of South America (FAO, 2011), expanding agricultural land to produce more food to feed these populations, is favoured by proponents of ‘productivism’ (Carolan, 2013). However, this may not be sustainable in Africa as this practice often results in environmental degradation, desertification, biodiversity loss, altered ecological balance and consequently land losses (Godfray *et al.*, 2010), this is especially true for drylands. Given the complexity of these challenges, attaining food security for an expanding population will require a greater focus on improving governance of food systems, reducing food waste and intensifying production per unit area sustainably. Underpinning food production with appropriate good agricultural practices could sustain current production; moreover, any form of intensification will need to harness the potential of appropriate drylands good agricultural practices (GAPs) that are both climate-smart and promote environmental resilience (Beddington *et al.*, 2012). It is against this backdrop that this chapter aims to determine through a review of the literature, the key challenges to drylands agriculture in the Sudano-Sahelian zone of Nigeria in the context of climate change and to examine the adequacy of smallholders’ current responses to these challenges.

2.1 Background and context

Adaptation to climate change has been a subject of controversy in the adaptation literature for West African drylands, and a body of knowledge exists on drylands adaptation and resource management in the Sahel focusing around livelihood strategies and local knowledge available to poor households for managing shocks and stresses (e.g. Snrech, 1995; Mortimore and Tiffen, 1995; Mortimore and Adams, 1999; Mortimore *et al.,* 2000; Mortimore, 2009; Mertz *et al.,* 2009). Such strategies include migration to urban areas, farm diversification, selling off assets and diversification of crops and livelihood options.

Other literature focused on the benefits of investments in drylands (Reij and Steeds, 2003), successes in land management and agriculture (Mortimore and Harris, 2005; Reij and Smaling 2008), and the effects of drought on food production and famine (Watts, 1983). Whilst there is merit in the use of these strategies for coping with short-term stresses, it is not clear whether such strategies can tackle predicted new climate change concerns and scenarios (World Bank, 1992; Boko *et al.,* 2007; Adger *et al.,* 2011; Frank and Penrose Buckley, 2012; Danjuma *et al.,* 2014). The inclusion of studies on long-term climate change adaptation (Adger *et al.,* 2011; Adger *et al.,* 2013) provides evidence that current climate risk management strategies are short-term, simplified and not sophisticated enough to solve evolving complex climatic challenges as well as being limited in scope to holistically tackle the multidimensional factors which interact to affect system resilience (Adger *et al.,* 2011).

In contrast to the previous approaches to dryland management, GAPs, emergent sustainable land management (SLM) and conservation agriculture (CA) practices have found application in dryland adaptation. Likewise, SLM promotes practices for the mitigation of climate change, biodiversity conservation and dryland restoration (Cowie *et al.*, 2011). Extensive research has been carried out to understand the benefits of those improved practices on productivity improvement; for example, the effects of mulching on improved yield (Kidane *et al.,* 2010); rooftop water harvesting (Knoop *et al.,* 2012); adoption of conservation and agro-forestry practices (FAO, 2009; Knoop *et al.,* 2012); and cover crops (Nana *et al.,* 2014). For an earlier review, see (Van Duivenbooden *et al.,* 2000; Pretty *et al.,* 2006).

Adaptation and adaptive capacity in Africa have become key considerations due to the vulnerability of African inhabitants. According to Boko *et al.* (2007), initial assessments reveal that many regions in Africa will be affected in diverse ways by the impacts of climate change and this will further limit opportunities for development and the attainment of the global Sustainable Development Goals. As little is known about the functioning of 'complex socio-economic, socio-cultural and biophysical systems, including a re-examination of possible myths of environmental change and of the links between climate change, adaptation, and development in Africa' (Boko *et al.,* 2007), a need exists for greater understanding of both the current and the anticipated impacts of climate change and associated vulnerabilities along with future adaptation pathways and options that will result from the interplay of various stressors on the adaptive capacities of African communities, especially those inhabiting dryland areas. Increasingly, settled agriculture in drylands is becoming the norm due to conflict with nomadic pastoralists. This review will focus very much on the settled farmers in drylands and does not attempt to address transhumance agriculture which will be a review in its own right.

2.2 An overview of the review method

A search of the literature (using the web of science) was carried out which focussed on "environmental challenges of drylands". This yielded 56 papers. Keywords like "desertification", "drought", "climate change", and "adaptation" were later used to further narrow the materials search which was used for this review. A further search of references cited in these papers was carried out with an emphasis on papers on the northern Nigerian drylands using Google Scholar. Although scarce, papers on West African Sahel were used to relate to the Nigerian drylands condition as well.

2.3 Drylands agriculture in sub-Saharan Africa- An overview

Drylands can be defined as being "characterized by scarcity of water, which constrains their two major interlinked services-primary production and nutrient cycling…with an aridity index value of less than 0.65" (Safriel and Adeel, 2005:626). Drylands are classified based on the aridity index (Table 2.1).

Table 2.1 Classification of drylands on the basis of Global Aridity Index (AI = P/PET).

Climatic zone	AI Value
Hyper-Arid	< 0.03
Arid	0.03 – 0.2
Semiarid	0.2 – 0.5
Dry sub-humid	0. 5 - 0.65
Humid	> 0.65

Source: (UNEP, 1997).

P=Precipitation; PET=Potential Evapotranspiration.

Elevated temperatures in the rainy season are responsible for the loss of excess rainfall via evaporation (Mortimore, 2005; Mwangi and Dohrn, 2008) making rainwater inadequate for production of water-thirsty crops in the drylands (NAP, 2000; MEA, 2005). However, dryland ecosystems provide forage, wood, freshwater, carbon sequestration, biodiversity management and food security to communities. The loss of ability of a dryland landscape to provide the services necessary for sustenance is referred to as desertification (D'Odorico *et al.*, 2013). The narrative that desertification is caused by biophysical or human factors arising due to pressure from 'overexploitation of land resources, leading to desertification, poverty, and reduced security' has been countered by its alternate paradigm that argues that 'adversity elicits innovation, leading to ingenious solutions for avoiding desertification' (Safriel and Adeel, 2008: 117). However, the alternate paradigm favoured by anti-desertification proponents (e.g Mortimore and Adams, 1999; Fairhead and Scoones, 2005; Toulmin and Brock, 2016) is not responsible for the unavoidable and continuous pressure on the unrenewable drylands resources which is projected to be further worsened by growing demand for land suitable for agriculture (Safriel and Adeel, 2008: 117). African drylands spread through 12 of the world's 20 less developed countries are home to about 260 million people who experience poor soil fertility and often low annual rainfall ranging from less than 200 to1000 mm (Mortimore and Adam, 1999).

2.4 Farming systems in drylands

In the 1950s, the agricultural uses of West African drylands ranged from cropping to animal husbandry. Drylands served as a medium for rain-fed or irrigated agriculture (Bayala *et al.,* 2012). Reliance on rain-fed agriculture in the drylands, when faced by poor rainfall regimes, leads to crop failure thereby exacerbating malnutrition, hunger and food insecurity (Nana *et al.,* 2014). Mono-cropping millet or sorghum or inter-crop with a low-density legume such as cowpea based on agro-ecological zone was previously practiced by drylands inhabitants (Van Duivenbooden *et al.,* 2000). However, in many drylands today the focus is gradually changing from sole cropping or livestock keeping to mixed farming systems and non-agricultural land uses (Hutchinson and Herrmann, 2008) including tourism and renewable resources production (Safriel *et al.,* 2005). Mixed cropping for food and fodder (Mortimore and Harris, 2005) is also practiced for improved resilience to drought, to build soil fertility and diversify diets (Kidane, 2010).

Livestock is vital to the dryland farming system but often neglected (Omanya and Pasternak, 2005). Pastoralists depend on livestock for their livelihood although not completely (Scoones, 1995; Kaye-Zwiebel and King, 2014). Livestock is valued for income, a source of improved diets, organic fertiliser and insurance against drought; livestock also serves as financial assets and a means of saving (Sansoucy, 1997; Batterbury and Mortimore, 2013). Herd sizes are built for risk management, wealth, and to gain social status (Notenbaert *et al.,* 2009). In the drylands of Africa, rainfall variability leads to decline in the production of biomass for animal consumption which together with the unavailability of surface water reduces the population of large animals (Mortimore, 1998).

Forty percent of SSA is semi-arid or arid rangeland (Kaye-Zwiebel and King, 2014) made up of desert ecosystems, dry woodlands, grasslands, and home to about 80 million rural pastoralists (Neely *et al.,* 2009; Notenbaert *et al.,* 2009). West African policymakers have sought to transform agro-pastoralism in local livelihoods by advocating for a shift to an ‘integrated system’ from pastoralism (Scoones and Wolmer, 2002). Pastoralists form 15% of the overall population in West and East Africa and together with urban dwellers, traders and farmers own about 60% of all ruminant livestock in Africa (Scoones, 1995). A controversy surrounded the idea of overgrazing causing degradation in rangelands anchored on a notion of a ‘carrying capacity’ that should not be exceeded under dry conditions (Mortimore *et al.,* 2008) which will threaten biodiversity and productivity due to the displacement of wildlife and plant species composition (Darkoh, 2003). Carrying capacity was argued to be a vague concept due to the ‘non-equilibrium dynamics’ of the region (Scoones, 1995: 25). Similarly, studies of pastoral systems in the African drylands regard drylands as ‘dynamic non-equilibrium ecological systems’, where there are no signs of degradation caused by over-grazing or high livestock population but rather the natural process of vegetation change in those areas taking place due to seasonal rainfall variation (Ellis and Swift, 1988; Dougill *et al.,* 1999; Briske *et al.,* 2017). In other words, livestock are at the mercy of the environment as opposed to changing it significantly.

In Nigeria, agriculture is broadly categorized into forestry, animal husbandry, crop production and fisheries. Animal husbandry is predominantly of the pastoral type and nomadic herdsmen, mostly Fulanis, move according to the seasons to the South in the dry season where deciduous forests fed livestock and to the North towards the Sahel in the wet season, thereby stabilising agriculture in such marginal environments (NAP, 2000; Darkoh, 2003). The pastoral system hitherto had an international aspect wherein the dry season herders from neighbouring Niger and Mali trooped into Nigeria in search of pastures for their stock (NAP, 2000). This has resulted in persistent conflict between farmers and pastoralists over limited resources and deprivation of access to potential grazing areas. Livestock and pastoral systems play a critical role in vulnerability reduction and adaptation enhancement. Pastoralists are knowledgeable about the environment and show some levels of flexibility in their ‘livelihood systems’ which is relevant in an unpredictable semi-arid and arid environment (Binns, 1995; Scoones, 1995). Poor access to grazing lands is a big constraint to pastoralism in Africa (Scoones, 1995). As a result, settled agriculture with crop and livestock integrated into a fixed plot is favoured as it is the norm now based on a mixed farming approach that is considered more environmentally friendly (Scoones and Wolmer, 2002). Pastoralists, however, have diverse cultures globally and in Africa, and have similar cultural and institutional adaptations that enhance resilience in drylands (Ellis, 1995); but a shift was recorded towards a model of ‘opportunistic stocking’ (Sandford, 1983). That is to increase livestock size in good years and prepare for losses in bad years (Mortimore *et al.,* 2008). Mobility is another adaptation strategy employed by pastoralists to manage temporary variability in their environments and to have access to widely distributed forage resources (McCabe, 1994; D’Odorico *et al.,* 2013). Confining these nomadic pastoralists to a sedentary (ranching) management could potentially reduce their resilience (MEA, 2005; Little, 2013) and consequently lead to the destruction of common resources fittingly described by Hardin (1968) as the ‘tragedy of the commons’.

Providing watering points for livestock close to the grazing areas in the dry season also helps in decreasing pasture and soil degradation caused by animal trampling in search of water (Burpee *et al.*, 2015). However, grazing around watering points artificially provided in ranches could distort the natural vegetation of the watering point area due to overgrazing and introduction of new plant seeds from animal dung (D’Odorico *et al.*, 2013). Conversely, other scholars argue that urination and dung deposition around the artificial watering points results in changes in the soil nutrient profile with elevated levels of nitrogen and phosphate (Smet and Ward, 2006). This nutrient profile determines where species can be established along the grazing level thereby affecting the productivity of rangeland (D’Odorico *et al.*, 2013). Despite the socio-ecological adaptations for resilience exhibited by pastoralists, most pastoralists systems are becoming unable to completely fulfil livelihood requirements of households and to maintain ecological resources due to population growth, economic and social modernisation and unfavourable land tenure systems (Notenbaert *et al.*, 2009). Indeed, diversification of income generation is increasing in pastoralist communities (Scoones and Wolmer, 2002).

Sustainable rangeland management and growing improved pasture could potentially contribute to carbon sequestration (ILRI, 2006), improve the livelihoods of approximately 1 billion people who depend on livestock and supply some income and food security to some 70 percent of the 880 million global poor (Neely *et al.*, 2009). Livestock are important sources of meat, milk, draft power and recycling of residue to manure for enriching the soil. However, the limitation of the livestock systems is that it requires some family labour to be allocated to management, especially where livestock needs to be controlled to allow crops to grow which in turn adds pressure to the existing labour in high demand for post-planting practices in drylands (Mortimore, 2003).

2.5 Smallholder agriculture in Sudano-Sahelian drylands

Smallholders, also referred to as small-scale, 'resource poor' (AGRA, 2014:15) or family farmers, are said to drive most African economies, employing limited resources and family labour (Morton, 2007). Indeed, one of the most effective models of farming has been the use of family labour, where work on the farm is carried out even in the absence of other resources such as capital (Netting, 1989). Smallholders are characterized as typically having two hectares or less (Craswell and Vlek, 2013), are poor, use primitive technology, yet supply 80 percent of food in SSA with each farmer having fields dispersed around the community (Johansen *et al.,* 2012); this makes smallholders the pillars of food security in such developing regions (Altieri, 2010; Tscharntke *et al.,* 2012). Shifting cultivation was a traditional farming system previously practiced in the drylands dependent on long fallow periods for soil replenishment (Mortimore and Tiffen, 1995; Mortimore and Adams, 1999). Reduction in land available for agriculture due to increased population and land degradation has made shifting cultivation impractical today with more smallholders becoming settled on reduced parcels of land.

Smallholders are faced with a seasonal fluctuation of labour with women playing key roles in production activities such as planting and harvesting (Mortimore and Adam, 1999; AGRA, 2014). In studies of four communities in northern Nigeria, Mortimore and Adams (1999) found smallholders to be typical of the smallholders generalised above, with no single unit representative of the whole. Hence, the need for a range of options for extension interventions (Mortimore and Adams, 1999). Furthermore, advice from extension service advisors is often generic and not appropriate for local conditions. A "one-size fits all" approach is not appropriate in such variable environments and current extension to farmer ratio of 1:3000-6000 is common in most African countries which exceeds the 1:500 recommended by the World Bank, making extension services ineffective. Apart from challenges of environmental degradation which this chapter focuses on, Nigerian smallholders are faced with challenges of poor credit, and lack of adequate improved inputs as well as poor access to the market, poor research and extension, all of which limit their production (Manyong *et al.*, 2005).

2.6 Environmental challenges of smallholder agriculture in drylands

Drylands agriculture is constrained by many factors which include; high and fluctuating temperatures (Mwangi and Dohrn, 2008), land degradation and desertification (Ola-Adams and Okali, 2008; D'Odorico *et al.,* 2013; Kiage, 2013; Adamu *et al.,* 2014; Burney *et al.,* 2014), drought (United States National Weather Service, 2008), soil erosion and climate change (Reed and Stringer, 2015). Other challenges include high livestock density, livestock diseases, and pests, low productivity of grazing lands, unavailability of improved fodder, poor livestock water supplies and poor agricultural productivity which exacerbates the poverty and food insecurity of rural households. Amongst the challenges, climate change and unpredictability may be regarded as the most limiting factor to agricultural productivity in the drylands (Kidane, 2010) especially due to its predicted impacts on other factors listed.

2.6.1 Climate change

Until recently, predictions of the effects of climate change on crop yield were mixed; some studies suggested that climate change, depending on the latitude of the area and irrigation application, has positive effects on crop yields (Cline, 2007; Kang *et al.,* 2009), while others argued that slight changes in climate have negative effects for agriculture (Downing and Parry, 1997; Ackerman and Stanton, 2013). Climate change is expected to cause a decline in the amount of land suitable for crop production in sub-Saharan Africa by about 3 percent, with the Sahelian belt recording a high decline (2.6%) (Lane and Jarvis, 2007).

Recent reports from Nigeria (Federal Ministry of Environment Climate Change Department, 2011) suggested droughts, temperature, and rainfall variability are increasing, or are likely to, in the Sahel region of the country due to climate change (Table 2.2); which may lead to losses in crop yields (Cline, 2008). This was further reinforced by the World Bank's prognosis for yield losses from climate change by the year 2050 (World Bank, 2009) (Figure 2.1).

Table 2.2 A summary of the projected trends in the key climatic change parameters for Nigeria is presented in the following table, by ecological zone.

Climate variables	Mangrove Zone	Rain forest	Tall grass (savanna)	Short grass (Sahel)
Temperature	↑	↑	↑	↑
Rainfall amount	↑	↑	↓	↓
Rainfall variability	↑	↑	↑	↑
Extreme rainfall events-droughts	↑	↑	↑	↑
Extreme rainfall events-storms and floods	↑	↑	↑	↑
Sea level rise	↑	NA	NA	NA
Legend: ↑likely increase or increase; ↓ likely decrease or decrease; NA not applicable				

Adapted from: Federal Ministry of Environment Climate Change Department (2011).

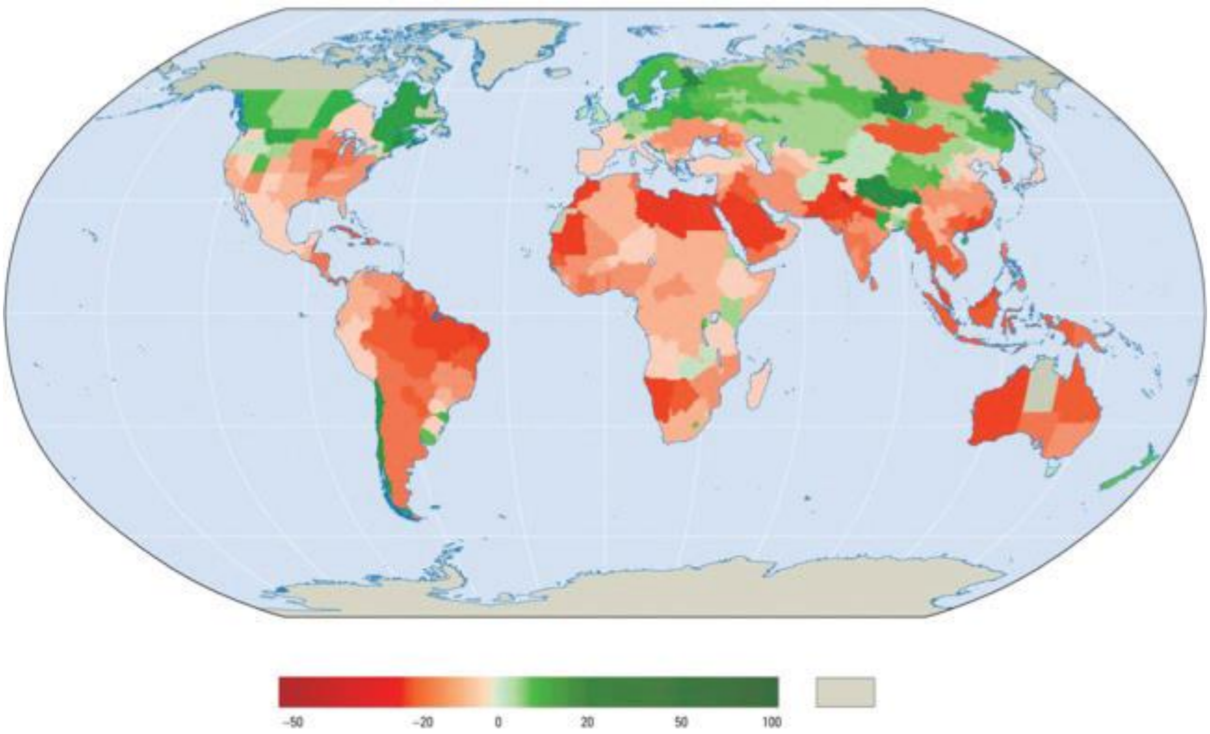


Figure 2.1 Impact of climate change on potential agricultural yields by 2050.

Source: World Bank, 2009.

Drylands are particularly sensitive to climate change and this will adversely influence net farm revenues across Africa (Kurukulasuriya and Mendelsohn, 2008; Kidane, 2010), thereby causing a shift in the areas used for the cultivation of diverse crops (Lane and Jarvis, 2007), as well as the degradation of ecosystems to a 'desertified' condition. This is against a backdrop of some 25 percent of the world's dryland areas already being affected by desertification (D'Odorico *et al.*, 2013). Cline (2008) asserts that most developing countries in the warmer part of the world already experience extreme temperatures that will further reduce crop yields when temperature further rises and water stress increases. Hence, unavailability of water will result in inhibited carbon dioxide fertilization. In contrast to this, other agronomic studies argue that global warming will only have a negligible effect on 'aggregate global food supply' as carbon dioxide fertilization with available water and variable temperature will lead to an average 30 percent yield increase with the doubling of CO_2 in the atmosphere (Reilly *et al.,* 1996). However, observed maximum and minimum temperatures and heat waves in Nigeria from 1981-2000 allied to changing rainfall trends (e.g. onset time, and length of rainy season (LRS)) show significant signs of the climate changing-most especially in the northern part of the country (Figures 2.2 and 2.3 respectively). This requires urgent action to reduce potential food losses from these climatic change impacts.

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Figure 2.2 Observed trends in maximum, minimum temperatures and heat wave in Nigeria in 1981-2000 with study locations circled.

Adapted from: Abiodun *et al.* (2011).

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Figure 2.3 Observed trends in rainfall, onset of rainfall, and length of rainy season (LRS) in Nigeria in 1981-2000 with study locations circled.

Adapted from: Abiodun *et al.* (2011).

2.6.2 Drought

Droughts are natural hazards resulting in vegetation loss and reduced land productivity (FAO, 2004) which are related to random variations in rainfall patterns (Giannini, 2016) that could occur in any part of the world, but cause less damage in other regions than in Africa (Kidane, 2010). Previous drought event that led to serious humanitarian crises in the Sahel and Horn of Africa have exposed the extent of the vulnerability of inhabitants of SSA drylands to extreme climate events (Morris *et al.*, 2016). This resulted in the loss of life and economic losses, migration out of these areas (Kidane, 2010), the ultimate result of which is limited availability of labour for farm activities in the out-migrating location. In Africa, drought has had significant effects on crop and livestock compared to other climate-related hazards (Figure 2.4).

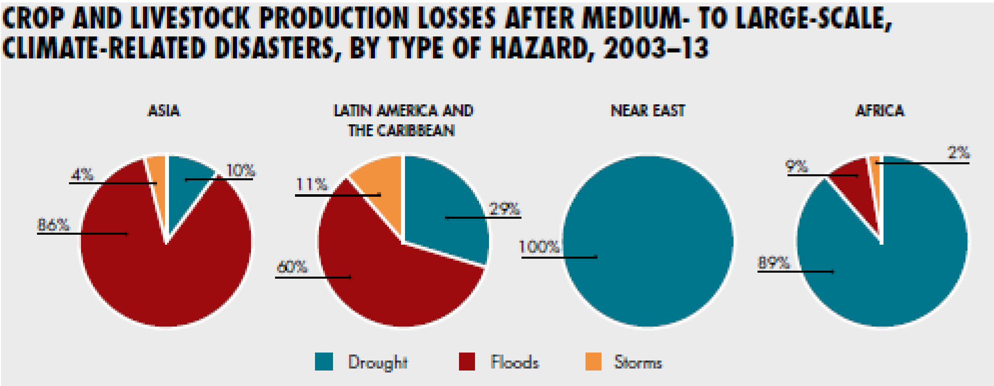


Figure 2.4 Losses from drought and other climate-related hazards to crop and livestock in Africa (2003-13).

Source: FAO. (2016b).

These drought events, aggravated by climate change, are projected to further expand the West African drylands, thereby affecting the livelihoods of millions of households while also slowing progress on poverty eradication (Cervigni and Morris, 2016). For example, Fraser *et al.* (2011), in their comparative study of how livelihood systems in diverse dryland regions are affected by drought, reported that dynamic environmental change models show climate change-induced drought events may drive dryland systems to cross biophysical limits, hence resulting in prolonged decreases in agricultural performance. Further, uncertainties surrounding the functioning of such systems emanates from the '"nonequilibrium"' nature of the semiarid environments. Also, other researchers argue that the most important challenge to Sahelian agriculture are not the total amount of rainfall, but the variability of supply in space and time (Watts, 1983; Cline, 2008). It is this kind of variability and not total rainfall that Cline (2008) argues the dryland inhabitants have traditionally adapted to in order to build resilience, through mobility, diversification, and pastoralism.

2.6.3 Desertification

Desertification is one of the key environmental challenges in Sudano-Sahelian Nigeria that has received much attention in the literature and refers to 'land degradation in arid, semi-arid and dry sub-humid areas resulting from numerous factors, including climatic variations and human activities' (D'Odorico *et al.,* 2013). Desertification leads to vegetative cover reduction which in turn leads to soil erosion; increased frequency of dust storms; loss of land productivity and of food security; biodiversity loss and change in plant community composition (D'Odorico *et al*., 2013).

Arguments about the advancement of the Sahara into the Sahel date back to the studies of Stebbing (1935) and Bovill (1921; cited in: Nicholson *et al.*, 1998), on the desiccation of the Senegal wells and rivers, and declined forests in parts of Nigeria, Niger and Mali. Later, desertification narratives resurfaced again in the 1960s when droughts resulted in famine in some Sahelian countries. This was further worsened by political instability in the region; prompting the United Nations Conference on Desertification (UNCOD) in Kenya in 1977. This conference resulted in increased attention to measures to reclaim affected areas, through the Plan of Action to Combat Desertification (PACD) coordinated by the United Nations Environmental Programme (UNEP). Additionally, the conference resulted in many publications produced on the severity (Batterbury and Warren, 2001; Hulme, 2001) and possible causes of the desertification (for a review see Herrmann and Hutchinson, 2005). This then metamorphosed into the current Convention to Combat Desertification (UNCCD) brought into force after the Rio summit in 1994.

However, a seeming duality exists on the advancing desertification claims, with other researchers reporting successes in drylands agriculture and environmental management in SSA (e.g. Reij and Smalling, 2008). Model studies underpinning these assertions (Nicholson *et al.*, 1998; Eklundh and Olsson, 2003; Anyamba and Tucker, 2005; Herrmann *et al.*, 2005; Olsson *et al.*, 2005; Helldén and Tottrup, 2008) show a significant re-greening of the Sahel in recent decades. Eklundh and Olsson (2003) further argued that the observed pattern of rainfall in the Sahel shows rainfall to have increased during the last few years.

Kiage (2013) argued that desertification is a naturally occurring phenomenon which humans have evolved with adaptive management of the ecosystem in SSA. Although the interaction of the biophysical and human factors could lead to degradation, the biophysical factors, such as climate, topography, vegetation cover and soil type interacting among themselves, could also lead to soil degradation. Similarly, some authors suggest that the severity of desertification effects on land has been over-stated as no change has been observed in the Sahelian vegetation cover (Tiffen and Mortimore, 2002; Fairhead and Scoones, 2005).

Considering the existing nuances between the contrasting views, exceptions exist to the generalization of the Sahelian 'regreening' as:

'parts of northern Nigeria and Sudan show areas where human impact hypothetically inhibited a greening trend in the order of magnitude expected from the positive trend in rainfall conditions' (Herrmann *et al.*, 2005: 402-403).

So, the 'regreening' of the vegetation cover was not all over the Sahel as the northern Nigerian drylands witnessed some form of desertification.

A recent review of desertification drivers, feedbacks and impacts concluded that the speedy process of desertification observed around regions of the globe reveals desertification to be linked with a 'transition between two stable states in bistable ecosystem dynamics' (D'Odorico *et al.,* 2013:329). In other words, the two stable states in the context of desertification paradigms correspond to vegetated and 'unvegetated' (i.e "nondegraded" and "degraded") states respectively. In 'bistable' systems, a disturbance (e.g. climate, and land use change) that causes a non-degraded land to transition to a degraded land when removed does not lead to the system regaining its initial structure, but it rather changes to its substitute stable state. Hence, it will be difficult for a 'bistable' system to revert to its original position, therefore making desertification irreversible.

In Nigeria, desertification and drought were identified as the two critical environmental challenges affecting the 15 states of the northern part of the country (Obioha, 2009) as they have led to a reduction of arable land of the area by 1-10km^2 per year (Odjugo, 2010), and are worsened by increases in livestock and human population (Stebbing, 1935; World Bank, 1992; Ruttan, 1997). To address the desertification menace will require more holistic water management that will recognise the place of water in social and ecological resilience building in an agricultural setting; as drylands are not without water but rather poor management of the available water to mitigate drought and desertification was the problem (Falkenmark and Rockström, 2008).

Herrmann and Hutchinson (2005) in a more comprehensive review of the desertification debate concluded that using an 'equilibrium mindset' to formulate policies in dealing with challenges of a non-equilibrium world will be inefficient. Hence the need for research in each of the broad disciplinary fields highlighted 'to proceed in parallel rather than in series'; that is, development research should take an interdisciplinary approach by encompassing both the social and ecological complexities of drylands.

2.6.4 Land degradation and soil erosion

In tropical Africa, land degradation and soil erosion constitute a major problem especially in SSA where they are perceived as a greater challenge than in the non-tropical areas (Kiage, 2013). Soil degradation is argued to be a limiting factor to future food security (Bindraban *et al.,* 2012) and the environmental quality of drylands (Adamu *et al.*, 2014). Bindraban *et al.,* (2012) illustrated the extent of the impact of degradation on crop production while also emphasizing the need for site-specific solutions based on farming systems and agro-ecological conditions. Also, the web-based land evaluation system by Ye and Van Ranst (2009) projected a decline of 9 percent in food crop yields by 2030 if soil degradation continues at double the present levels. Obioha (2009) reported that erosion by wind has had significant effects in the Nigerian Sahel states of Bauchi, Sokoto, Kano, Adamawa, Yobe, Borno, Katsina, Jigawa, Kebbi and Zamfara due to drought conditions of these areas, as drought and desertification operate together (Nicholson *et al.,* 1998). Mortimore and Harris (2005) in the study of village/farm district and national levels of the drylands found a contrary result. The study found that food output per capita and yields per hectare increased, having been influenced by policy rather than soil degradation or rainfall over the long term. This increase provided evidence of farmers' successes in sustained production and investments in soil fertility management. Mortimore and Adams (1999) further argued that increased population in the Sahel makes labour available to invest in soil maintenance to avoid degradation; however, this also means more mouths to feed.

This school of thought has been countered by recent model studies on the extent of drylands degradation in Nigeria where soil erosion leads to fertility loss resulting in poor productivity of crops (Adamu *et al.,* 2014). This was further underpinned by "The Climate Change–Impacts, Adaptation and Vulnerability Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change" (Boko *et al.,* 2007) that argued, key economic sectors in Africa are at risk of current climate change effects which will be further worsened by prevailing development challenges which include: ecosystem degradation; endemic poverty, limited access to capital, including markets, complex governance, and institutional dimensions; infrastructure and technology; and complex disasters and conflicts.

2.6.5 Population

Each side of the debate on the relationship between population growth and environmental degradation has its strengths and weaknesses. It can be argued that population has a negative effect on the environment. More recent studies have linked desertification to the effect of population pressure on land resources, as 2 billion people worldwide reside in drylands with 90% of those living in developing countries (Fraser *et al.,* 2011; D'Odorico *et al.,* 2013). Furthermore, population distribution and growth, impacts activities that cause degradation to soils (Koontz *et al.*, 2013), reduce fallow periods (World Bank, 1992; Ruttan, 1997) then, in a bid to produce more food, lead to more forest cleared, and leading to further degradation (Darkoh, 2003). Studies have also established links between increased aridity, land degradation, population explosion and climatic changes (Adamu *et al.,* 2014) which over the next decades will mount further pressure on the global food systems (Foresight, 2011).

One school of thought favours the Malthusian hypothesis which states that where population increases land becomes scarce, subsequently leading to degradation and over-cultivation (Darkoh, 2003). Livestock populations have also experienced growth around towns and villages in drylands, as this together with open range management, makes the land overgrazed and subject to erosion (Tabor, 1995; Kidane, 2010). Contrarily, another school of thought argued that population growth leads to positive effects on the environment. For example, the land improvements in Machakos district in Kenya (1930-1990) where the Akamba of

Machakos showed examples of conserving natural resources and improving their tree plantations while practicing agriculture under a growing population (Mortimore and Tiffen, 1995). The Machakos' case is argued to follow the Boserupian hypothesis that population increases lead to more labour available to be invested in soil conservation (Boserup, 1965). Additional views support this assertion that more people will mean more crops, more time for animal tending and more labour to invest in land improvement (Mortimore and Adams, 1999). More people will lead to sustainable land management while reducing populations could reduce the labour available to work with new technology (Vosti and Reardon, 1997a; Fairhead and Scoones, 2005).

These assertions require scrutiny because unlike in developed countries, social organisations in many African countries do not necessarily conform to the Boserupian and Kuznets' hypotheses which states that the early stages of economic development in a country will result in environmental degradation, and then after the attainment of certain levels of income, that degradation will experience reduction whilst development continues and transforms into an investment in renewables as resources become available (Kuznets, 1955). According to Darkoh (2003), this then leads to the successful addressing of land degradation challenges in Africa. A likely explanation for the failure of the Boserupian and Kuznets' hypothesis is that, once the soil is destroyed, it takes generations to re-create. As the population-degradation nexus is not a clear-cut relationship, linked neither to any cultural nor social group, there is a need for a 'guarded and thorough analysis' to further explain the role population plays in the desertification challenge (Thomas and Middleton, 1994; Reynolds *et al.*, 2007). Population growth leads to short fallow and consequently soil degradation and declining productivity, hence, efforts at the sustainability of more 'modern agricultural systems' will be more desirable now than ever (Ruttan, 1997; UNCTAD, 2009).

2.6.6 Poverty

Despite the progress recorded in poverty reduction over past decades from improvements in the food crop production technology, rural poverty remains too high and continues to grow leading to the destruction of lives whilst undermining the environment and development (Vosti and Reardon, 1997a). As a survival strategy, the poor often exploit their resources leading to degradation and resilience reduction (Downing and Parry, 1997; Spencer and Polson, 1997).

Poverty is not always significant in the occurrence of desertification as desertification also occurs in developed countries' drylands such as North America and Australia (Thomas and Middleton, 1994). Likewise, trade-offs are envisaged in agro-ecological areas where intensification of agriculture is not favoured, as poverty reduction could entail more land expansion in the interim thus resulting in less poverty reduction and land degradation over a long time. Whereas, in favourable agro-climatic zones, intensification may actually lead to growth with less pressure on marginal and grazing lands (Vosti and Reardon, 1997a; Vanlauwe *et al.*, 2014). In terms of livestock ownership, poorer households with fewer livestock than their richer counterparts, exert less pressure with regards to pasture production on the semi-arid lands of West Africa (Reardon and Vosti, 1997b; Kidane, 2010).

However, many parts of the developing world experience fast-growing populations with slow growth in agriculture and food production deficits which could result in increased food prices with negative consequences for the poor and economic growth (Vosti and Reardon, 1997a; Holmen and Hyden, 2011). Furthermore, the eradication of poverty in SSA will have to be through the improvement of agriculture since poverty in this region occurs mostly among rural smallholders (Spencer and Polson, 1997; Holmen, 2011). Nonetheless, not all poor people are smallholders (Murphy, 2012).

2.7 Adaptation and risks responses to dryland challenges

Risks and uncertainties are important in agriculture due to their influence on the decision-making process with potential results in both inefficiency and food insecurity (Thornton and Wilkens, 1998). Risk is defined by the Royal Society (1992) as a mix of the frequency or probability, "of occurrence of a defined hazard and the magnitude of the consequences of the occurrence". According to Flemig *et al.* (2014), risk management could be soft or hard, reactive or proactive; proactive risk management evades risk occurrence or decreases its severity while reactive risk management tackles risks that have occurred. Adaptation to climate change has been likened to risk management (Hellmuth *et al.*, 2007). As discussed in the background to this chapter, different perspectives exist about the capacity of drylands inhabitants to adapt to the impacts of climate change, and to explore these contrasting paradigms, it is relevant that this concept of drylands adaptation, which in the last decade has become a persuasive and conventional belief around the globe, is located within the context of existing literature.

A school of thought argues that African dryland inhabitants have evolved with adaptive capacities to local environmental challenges, as these experiences equate current climate change scenario (Mertz *et al.*, 2009; Mortimore and Tiffen, 1995; Mortimore and Adams, 1999; Mortimore *et al.,* 2000; Mortimore, 2009). For instance, a study into effective livelihood adaptation to climate change disturbance in communities in Mozambique by Osbahr and colleagues found that individuals adapt differently to environmental stresses. Some households adapted through a reduction in the use of available resources with the sale of assets considered a last resort during critical periods and only undertaken when that reduction in assets did not increase long-term vulnerability (Osbahr *et al.,* 2008). In the Nwadjahane community, social networks proved very useful in supplying resources for coping with immediate stresses through reciprocal gifts exchange, labour exchange (informal), and labour exchange for food. Although, when reciprocal limits were exceeded, households became vulnerable-most especially in the very poor and female-headed households (Osbahr *et al.*, 2008).

In Northern Nigeria, Mortimore and Adams (2001) identified adaptive approaches employed by dryland farmers to cope with the five key dimensions of the drought crisis experienced in 1972-1974 (Table 2.3). Of the mix of adaptation practices highlighted in the literature, diversification (of livelihood and crops), migration, negotiating the rain[1], managing biodiversity, livestock integration, off-farm income generating activities; trade (Sana'a-a Hausa word for business) and diversification of production systems all featured prominently (Mortimore and Adams, 1999; Mortimore and Adams, 2001; Thomas, 2008b; Batterbury and Mortimore, 2013). Also, as a reflection of diversity, poor farmers grew different varieties of the same crop on the same field at the same time as insurance against future uncertainties and display of system resilience (Altieri, 2010).

Diversification within and outside agriculture has been practiced as a risk management or spreading strategy by households (Ellis, 2000; O'Laughlin, 2002; Ellis and Allison, 2005) to survive their harsh conditions (Mortimore and Adams, 1999). Household heads in Northern Nigeria were found to be the decision makers to diversify sources of income (Irohibe and Agwu, 2014). Apart from livelihood diversification, food sources (Oruonye, 2013) and farming

[1] This implies the ability of farmers to manage production systems amid fluctuating rainfall (Mortimore and Adams, 1999).

systems were also diversified to serve as insurance against pest and disease infestations that could lead to losses and for balanced nutrition (Sherwood, 2013). Research conducted in Kano-north-western Nigeria also illustrated the efficiency and flexibility of livelihood and farming systems through the flexible rationing of family labour based on priority farm operations and determined by the variability of rainfall which influences what is grown and when (Mortimore, 2003).

Table 2.3 Crises and Farmers' Strategic Adaptations in the Sahel.

Adapted from: Mortimore and Adams (2001).

Devereux (2001) distinguished coping strategies and risk management on issues related to economic and environmental insecurities. He argued that risk exposure is generic and has effects on large populations whereas susceptibility to these risks is specific to individual households and individuals; hence this susceptibility often depends on coping strategies and risk management which themselves rely on existing social systems, and the household's social and economic position (Devereux, 2001). Other researchers also argue that vulnerable African populations are 'active agents of change' armed with knowledge and skills and not 'passive victims' (Reij and Steeds, 2003; Tschakert and Dietrich, 2010). This is corroborated by Batterbury and Mortimore (2013) who opined that local adaptive strategies to drought in the West African Sahel is a classic example of the existing adaptive capacity displayed by Northern

Nigerian farmers of existing capabilities to survive harsh drought-prone environment without any external support.

Contrarily, the second school of thought asserts that current adaptation strategies displayed by African smallholders are insufficient to tackle climate change impacts never previously experienced (World Bank, 1992; Boko *et al.,* 2007; Adger *et al.,* 2011; Frank and Penrose Buckley, 2012; Danjuma *et al.,* 2014), as opinions from policy circles portray African dryland inhabitants to be people in need of assistance and government or donor intervention to cope with environmental challenges due to low adaptive capacity (Thomas and Twyman, 2005), poverty and population growth (Neely *et al.,* 2009).

Aside from reduced resilience to desertification, drought, and degradation, there is increased recognition by development stakeholders of potentials for adaptation, carbon sequestration and storage in soils of pastoral and agro-pastoral drylands systems which should be highlighted in the 'post-Kyoto mechanisms' (Neely *et al.,* 2009). To achieve these potentials Neely *et al.* (2009) argued, it will require specialised capacity building and targeted incentives to sustainably manage these degraded ecosystems, underpinned by 'pro-poor livestock policies, integrated processes that address natural and social dimensions, and funding mechanisms that enable multi-stakeholder engagement'.

2.8 Role of indigenous knowledge in adaptation

Indigenous knowledge, also known as ethnoscience, native, folk, local, and traditional knowledge could be defined in its broadest sense in relation to agriculture as knowledge, techniques, and skills acquired over time because of constant use of the environment (Dawoe *et al.,* 2012). Notably, indigenous knowledge formed over a long time illustrates the role indigenous mechanisms played in coping with real-life challenges (Fabiyi and Oloukoi, 2013). In agriculture, indigenous knowledge has been found to form the basis for grass-roots people's decision-making (Kolawole, 2013). Soil management has been given relevance by local farmers for agriculture to be successful (Venkateswarlu *et al.,* 2013). Farmers possess indigenous knowledge of soils and management techniques for fertility maintenance which could also be used to develop interventions for sustaining farm productivity (Dawoe *et al.,* 2012).

Despite the importance in solving world environmental challenges, science has generally not recognised the value of local knowledge in the design and application of science-based adaptation and mitigation strategies (Mertz *et al.,* 2009; Ajani *et al.,* 2013) as it is not well understood and documented (Fabiyi and Oloukoi, 2013). Also, other concerns exist that the future may bring extreme experiences that have not been seen in the past, thereby limiting the utility of traditional and local knowledge (Speranza *et al.*, 2010). Therefore, Burbi *et al.* (2013) argue that translational research offers a platform for harmonising indigenous knowledge and science; translational research considers smallholder farmers' knowledge and provides guidance and advice to these farmers on how to implement scientifically proven GAPs that will mitigate the effects of climate change on agricultural productivity using a bottom-up approach.

2.9 Agricultural development in Nigeria

This part of the chapter moves on to discuss in greater detail the situation of agriculture in Nigeria and the significance of the Nigerian drylands to food security. Nigeria has a land area of 924,000 square kilometres of which 78 percent is devoted to agriculture, 37.3% to arable land, 7.4% to permanent crops and 33.3% to permanent pasture. Agriculture is the mainstay of the Nigerian economy responsible for the supply of food and fibre, and a major contributor to GDP. The sector employs approximately 70 percent of the population. Despite the agricultural potentials highlighted, Nigeria's dependency on food imports continues to grow as exemplified by cereal imports to feed its growing population (Figure 2.5). This is because previous government policies on food security were import based due to the boom in the oil sector from the early 1970s which favoured cheap food imports. Notwithstanding the importance of this sector to the Nigerian economy, less attention has been paid to the sector in the past decades. For instance, Nigerian public spending for agriculture is at an average 4.6 percent for the period 2008 to 2012 and continues to decrease (Table 2.4) (Olomola *et al.*, 2014). This is below the 10 percent agricultural spending of national budgets agreed by African leaders at the Maputo declaration in 2003 as part of the Comprehensive African Agricultural Development Programme (CAADP) which is an integral part of the New Partnership for African

Development (NEPAD) saddled with the responsibility of improving the performance of agriculture in Africa.

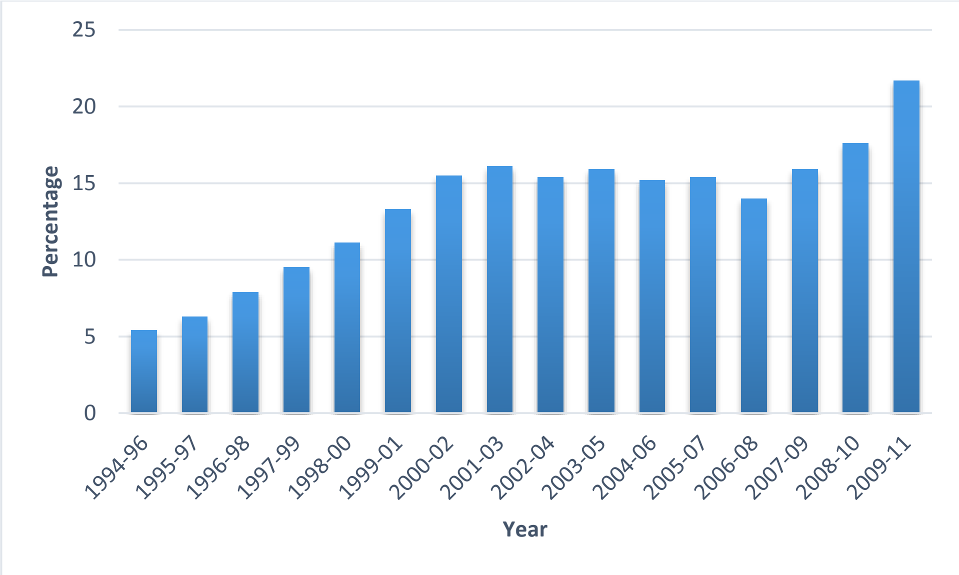


Figure 2.5 Percent cereal import dependency for Nigeria 1994-2011.
Data Source: FAO. (2015b).

Table 2.4 Federal agricultural spending as a share of total spending, 2008–2012 (%).
Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Source: Olomola *et al.* (2014).

The agricultural sector's contribution to GDP as a component of the non-oil sector has shown some considerable reduction from 41.3 percent in 1970 to 23.11 percent in 2015 (Table 2.5). While in absolute terms, agricultural GDP (in Nigerian Naira-NGN) has witnessed steady growth from 2005 until 2015 and only the oil sector experienced variation as captured in the industry contribution to GDP (Figure 2.6). Recent percentage growth of the agricultural sector contribution to GDP is attributed to current government policies on diversification occasioned by dwindling international oil prices (National Bureau of Statistics, 2016).

Table 2.5 Contribution (%) of sectors to the Nigerian economy (1970, 80, 90&2000; 2010-2015).

	1970	**1980**	**1990**	**2000**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Oil sector GDP	6.0	29.1	39.3	48.2	42.68	40.95	37.01	11.24	10.44	9.61
Non-oil sector GDP	94.0	70.9	60.7	51.8	57.32	59.05	62.99	89.76	89.56	90.39
Agriculture	41.3	20.6	29.7	26.3	30.35	31.08	23.91	23.33	22.91	23.11
Industry	7.8	16.4	7.8	4.5	ND	ND	25.61	24.81	24.93	23.71
Services	45.0	33.8	23.6	21.0	ND	ND	50.48	51.86	52.16	53.18

Adapted from: NBS/IMF in: World Bank and UK-DFID (2007); National Bureau of Statistics (2016) ND=Data unavailable to authors.

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Figure 2.6 Annual Sectoral contribution to GDP at 2010 Constant Basic Prices (Naira Million) 1985-95 & 2005-2015.

Data source: CBN (2017).

At the global level, the FAO estimated that the global food prices rise between the year 2003-2007, subjected about 923 million people to hunger globally (FAO, 2008). This constitutes a significant increase by over 80 million compared to the 1990-1992 scenarios. In the same period, 24 million additional population were thrown into hunger in Africa. Smallholders who are poor, landless and in rural areas are mostly the victims of this hunger condition (FAO, 2008). Aside from having the highest proportion of the global poor (Figure 2.7), SSA poor are largely employed in agriculture (Poulton *et al.*, 2005) with about 31% of the population employed in the Nigerian agricultural sector. Hence, development of the agricultural sector offers a platform for eradicating poverty since most of the poor are dependent on agriculture (Rogers, 1999). Poor productivity of Africa's agriculture which is not in tandem with the continent's population trajectory will further exacerbate the continent's food security crises (World Bank, 2007). The productivity of the agricultural sector in SSA just like in the case of the Asian Green Revolution will be driven by smallholders who control most of the land holdings (Larson and Otsuka, 2016). However, not necessarily under an industrialised model.

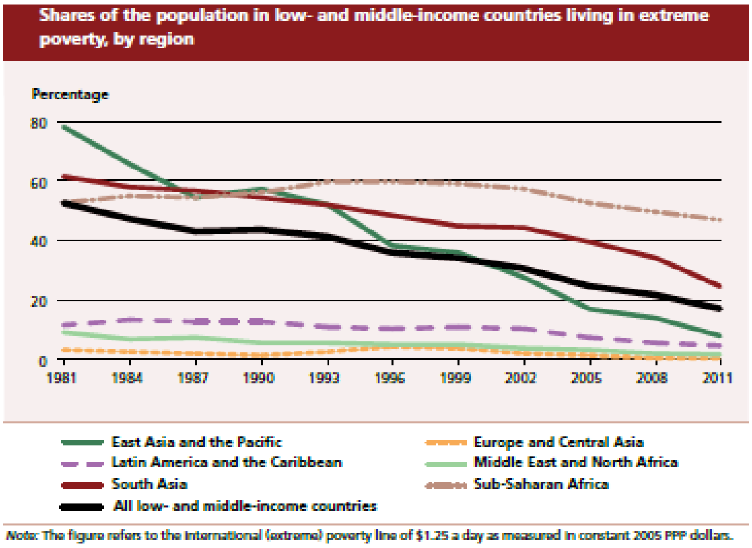


Figure 2.7 Percentage of the poor in low- and middle-income countries living on $1.25/ day.

Source: FAO (2015b).

Agricultural productivity in Nigeria is considered very low because of poor institutional and biophysical factors such as poor soil parent material (FAO, 1996), climate change and land degradation. Previous development plans for Nigeria pursued policies towards increasing productivity through the use of new technology making farmers commercially focused and neglecting the smallholders who farm for subsistence (Wallace, 1981). Poor rural farming households have mostly been at the receiving end of this productivity constraint. Population increase in Nigeria which is currently the 9^{th} populous country in the World and the most populous in Africa is projected to reach over 200 million people by 2025, thereby adding to the environmental crises and consequently food insecurity.

The agricultural sector can support the pursuit of combating hunger, poverty, and unemployment in the course of economic development in Nigeria (Olomola *et al.*, 2014). This will potentially be possible through public sector investment in agriculture due to market failure, poverty, and inequality. Market failure in agriculture is common in developing countries as agricultural technologies necessary for farmers to improve their productivity comes with a cost from the private sector which is beyond rural farmers' reach. Public sector investment in agricultural research and development is mostly financed by Official Development Assistance (ODA) to most developing countries including Nigeria (FAO, 2012). However, for Nigeria ODA is not very significant in budget financing support which was a paltry US$ 280 million as at 2006 (IFAD, 2009). Hence, the need for appropriately targeted technologies to support these rural poor farmers to be sustainable.

For agricultural growth to be sustained, a new approach to agricultural production in the country is required, as a vibrant agricultural sector is critical to the food security of a country, job creation, foreign exchange earnings and the provision of industrial raw materials (Ogen, 2007).

2.10. Agro-ecological and vegetation zones

Agro-ecological zones are classified based on temperature, rainfall variability, and humidity as well as soil and landform; all of which determine the type of native plants that can thrive and the potential to introduce key crops to the zone (Aregheore, 2009). Climatic zone and vegetation can also be used to determine the capacity to sequester carbon (Neely *et al.*, 2009). Nigeria is divided into forest and savannah zones which are further sub-divided into six vegetation zones (Map 4.1), however, only the zones relevant to this study are highlighted (Table 2.6).

Table 2.6 Nigerian agro-ecological zones relevant to this study with their characteristics.

Agro-ecological zone	Characteristics
Guinea savannah	-Covers 405, 200 km^2 being the largest zone made up of southern and northern Guinea savannah. -Characterized by grasses such as *Pennisetum*, *Panicum*, *Andropogon*, *Hyparrhenia*, *Chloris*, *Paspalum & Melinis*. -Annual rainfall is 1100-1500 mm with wet season lasting 6-8 months -Extends from the Zaria area to the southern part of the country. -Trees found include *Daniellia oliveri* (false balsam Copaiba), *Afzeila*, *Lophira*, *Terminalia*, *Khaya senegalensis* (poor mahogany) (all in southern Guinea savannah). In the northern Guinea savannah are found *Isoberlina doka & I. tomentosa*, locust bean tree *(Parkia filicoidea)*, shea butter tree *(Butyrospermum parkii) &* mangoes *(Mangifera indica)*.
Sudan savannah	-Covers 241, 800 km^2 of mostly natural grassland, made up of most parts of Kano, Sokoto, Borno and some parts of Bauchi and Kaduna states. -Mean annual rainfall amount ranges from 600-1000 mm over a period of 3 to 5 months. -Favours legumes (groundnuts, cowpea), cereals (millet, sorghum), and livestock (cattle, small ruminants and poultry). -Has short grasses with thick or coarse continuous grass cover & trees found include locust bean tree *(Parkia filicoidea)*, mangoes *(Mangifera indica) & tamarind tree (Tamarindus indica*). -Most of the zone lies in the tse-tse fly free zone which favours ruminant livestock breeding (e.g sheep, goat, cattle, camels, donkeys and horses).
Sahel savannah	-Covers about 20, 812 km^2 of land, majorly Borno state on the verge of the Sahara. -Supports groundnuts, millet, irrigated rice and wheat. -Mean annual rainfall is low (400-600 mm per annum) with the rainy season lasting between 3-4 months with sparse and short grasses. -Plants found include *Cenchrus biflorus & Acacia raddiana* with shrubs such as African myrr (*Commiphora africana*) & *Leptadenia spartum*.

Data-source: Aregheore (2009); Idachaba (1980) and Okpara *et al.* (2013).

The Nigerian Sahel, the focus of this study, is estimated to cover about 5-10 percent of the country's land mass and has increasingly been expanding into the Sudan zone. Indeed, some authors now consider the two zones together as the 'sudano-sahelian' zone (NAP, 2000). The sudano-sahelian zone predominantly consists of thorny tree vegetation, and open grassland with commiphora and acacia trees (Idachaba, 1980) which is typical of other African drylands such as Ethiopia (Coppock, 2016). The sudano-sahelian zones make up the Nigerian drylands which are the rangelands for grazing and fodder that support high livestock populations (NAP, 2000). In Nigeria, agriculture is mostly practiced in the rainy season which lasts about four months in the northernmost part of the country. Soil types, sunshine, rainfall, ground and surface water all influence agricultural production and affect incomes and labour use which have implications for poverty reduction and environmental sustainability (Vosti and Reardon, 1997b). It is important, however, to measure the soil water readily available for crop use as some rainwater is lost through run-off and evaporation. In the section that follows, research and policies on dryland agriculture in Nigeria will be discussed.

2.10.1 Research and Policy Developments for Nigerian drylands

Based on a report by Idachaba (1980), agricultural research in Nigeria initially focussed around export crops such as cocoa, cotton, rubber, and groundnuts to feed the British industries, with research centres situated close to the areas with high potential for producing these crops. The emphasis on the production of these crops heightened in the light of the outbreak of the World War II when the United Kingdom lost raw materials supply from the Far East and due to the foreign exchange contribution to the Nigerian economy which saw a high (63 percent) allocation of research funding for the Second National Development Plan (1970-1974) as against 33 percent for food crops. However, the Nigerian agricultural research failed to improve production and yield in the long term amid income and population increases as major declines were recorded for maize from 1968/69-1974/75 and general crop output fluctuating on a yearly basis with sorghum, soybean, and millet being mostly unstable whereas cocoa, groundnuts, and cotton appreciated because of research. The challenges to agricultural research at the time were linked to a non-smallholder focus, insufficient funding, inadequate staff to manage the projects, inadequate research equipment and materials, poor research delivery system and low research turn-over. Other challenges include: neglect of irrigation and other major input research which had a direct consequence for dryland farmers.

Before Nigeria's independence in 1960, direct emphasis on drylands research was lacking. However, attempts to locate a suitable area for cotton research led to the establishment of a research station in Samaru, Zaria in present Kaduna State in 1922 being a cotton zone and strategic as an assembly point for shipment of agricultural commodities to Europe. This station later extended its branches by creating a groundnut research centre in present Kano State as a hub for the groundnut producing areas. The Samaru station later became the Institute for Agricultural Research and Special services after the Ahmadu Bello University, Zaria was created with cotton being the only independent crop unit and the first commodity to have a research program and later to integrate research in key dryland crops such as sorghum, millet, wheat, and barley. Other research institutes later established in Samaru were National Animal Production Research Institute (NAPRI) with focus on Livestock, Agricultural Extension Research and Liaison Services (AERLS) with focus on extension services (Idachaba, 1980).

Until 2012 there was no specific coordinating centre for solely researching on dryland issues as most research was crop-specific which cut across the research institutes in Northern Nigeria. In February 2012 Bayero University, Kano-Nigeria won a grant from the MacArthur Foundation to assist in the establishment of the Centre for Dryland Agriculture with specific focus on responding to challenges of dry areas for enhancing food security, sustainable natural resource use and improved livelihoods of smallholders through 'demand-driven' capacity building and research and engagement with other relevant stakeholders.

2.11 Chapter summary

Adaptation strategies to challenges in northern Nigerian drylands in line with traditional farming systems for the area already exist through active management of short-term environmental risks and challenges to improved production with environmental responsibility. Despite these, there are concerns about long-term climatic change events, drought, desertification, population explosion and poverty which could limit resilience enhancement in those areas, especially if new environmental challenges exceed those previously experienced. Also, the current extension service advisor-farmer ratio is large and has proven inadequate due to fewer extension agents serving more farmers. Hence, the need for more research on integrating external knowledge in the form of GAPs that are site-specific with local knowledge for enhancing drylands households' resilience in the face of climate change (Beddington *et al.*, 2012). Allied to this, engaging smallholders by a new and expanded model extension service in the threats that climate change is likely to impose on them is important to allow their adaptive strategies to further develop. After highlighting the challenges of dryland agriculture, the next chapter will explore how it relates to sustainability and food security in the drylands.

CHAPTER THREE

Sustainable agriculture and food security in Nigerian drylands

---

This chapter will address the following aims and objectives: to;

- explore livelihood and sustainability in drylands agriculture for food security in Nigeria;
- review potential strategies for sustainability of dryland farming and food security;
- explore environmental policies for Nigerian drylands sustainability, and a conceptual framework for smallholders' resilience enhancement against the backdrop of environmental challenges will be advanced.

3.1 Agriculture and Sustainability

The Sustainability paradigm entered the agricultural development discourse decades ago when scholars started writing about the need for humans to act responsibly towards the environment. Notable among these writings include: ‘The Silent Spring’ (Carson, 1962) – a precursor to the ‘modern environmental movement’, and the report of the World Commission on Environment and Development (WCED), ‘Our Common Future’ (WCED, 1987). The report advocated for the need to care for the environment to ensure intergenerational equity. Then came climate change, population growth and other related environmental challenges that increased pressure on food security objectives in vulnerable regions such as the drylands (Horlings and Marsden, 2011). Sustainable agriculture is argued to be the panacea to food security amidst these challenges in sub-Saharan Africa (SSA) (Adenle *et al.,* 2017).

A seeming contrast exists between sustainability goals and sustainable development. While sustainability focusses on ‘needed value changes’, sustainable development is concerned about ‘technological fix’ making it a rather vague concept according to Robinson (2004). However, other authors argue that sustainability concerns in the agricultural systems are anchored on developing technologies and practices undamaging to environmental goods and services; which are accessible and effective for farmers, leading to improvements in their productivity, profitability and social benefits in the short and long run (Granatstein, 1992; Øygard *et al.,* 1999; Pretty *et al.,* 2006; Pretty, 2008; Folke *et al.,* 2010; Juma, 2015). This is because land productivity in SSA compared to other regions is low (Figure 3.1).

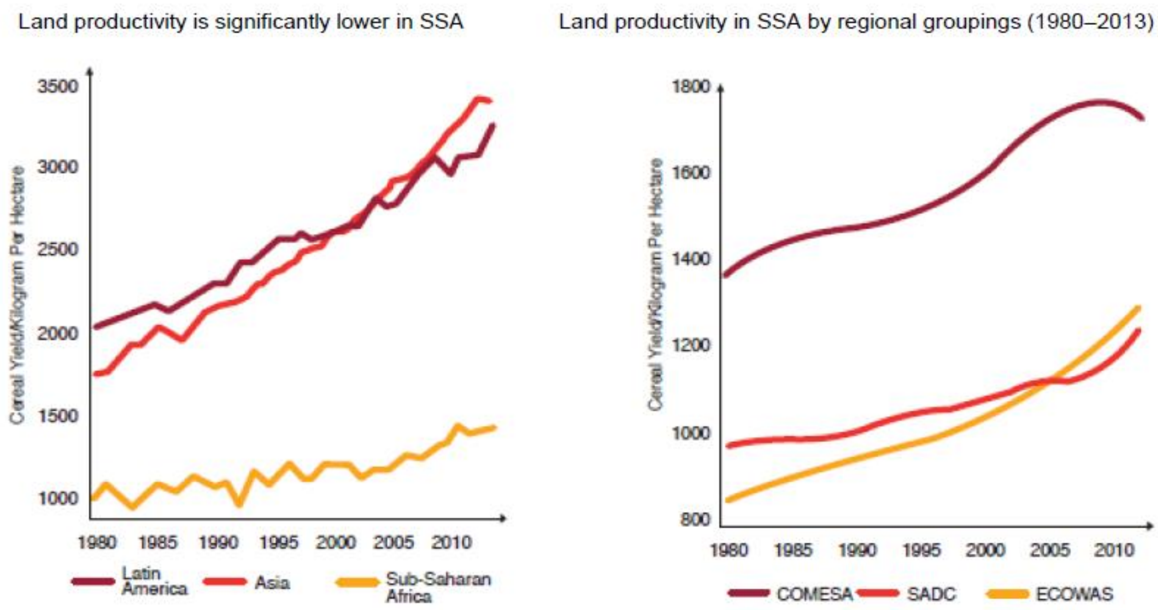


Figure 3.1 Land productivity is low in SSA.
Source: IBRD/World Bank (2015).

The Sustainability concept is strongly related to resilience and adaptive capacity of a farming system (Folke, 2006), and are complementary (Figure 3.2) (AGRA, 2016). According to Gliessman (2005:106-107) to 'reintegrate sustainability, the emergent qualities of system resistance and resiliency must once again play a determining role in agroecosystem design and management'.

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Figure 3.2 Resilience and Sustainability as complementary concepts.
Source: Tendall *et al.* (2015)

3.2 Sustainability of smallholder agriculture and food security

The central tenet of the sustainability paradigm is to deliver food in a safe and environmentally benign way. That is, in a socially acceptable, economically viable and environmentally friendly manner (Pretty, 2008; Adenle *et al.*, 2017). According to FAO (2006:1) "Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". An essential element of sustainable agriculture is that it underpins food security at the household, regional and national levels. National and local food availability are considered precursors to household food security as it is dependent on both the demand and supply side (Middleton, 2013). However, the famines experienced in East Africa and the Sahel in the 1970s negated this assertion revealing that 'adequate national and international supplies do not necessarily prevent extensive food insecurity' at the household level (Middleton, 2013: 312) and per capita consumption levels of essential major commodities in developing countries are low (Figure 3.3) (Alexandratos and Bruinsma, 2012).

Figure 3.3 Food consumption per capita, major commodities (kg/person/year).
Source: Alexandratos and Bruinsma (2012).

Persistent food insecurity, famine and malnutrition in the developing world, most especially SSA, has become a polemic and a mainstream topic of discourse. Some scholars argue the way out of this enigma is a shift to a large-scale commercial agricultural model- targeted towards an African Green Revolution and modelled after the Asian Green revolution. This uses improved crop varieties, tractor mounted implements, chemical input and large irrigation infrastructure in a monocrop system leading to disruption of time-tested local practices (Eicher, 2003; Pennisi, 2008; Middleton, 2013; Toulmin and Brock, 2016). Intensification in this case is through the use of more capital (pesticides, machinery, and fertilizers) as opposed to more labour in a mixed cropping system (Adams and Mortimore, 1997). However, the large-scale nature of this operation involves cultivating large areas easily and quickly while overlooking the details about sustainability in a rush to produce more food, and as a result, this questions the 'long-term sustainability' of such an approach (Altieri, 2000; Horlings and Marsden, 2011).

Before the population explosion around the 1950s in SSA, agriculture was favoured by the availability of vast lands which allowed for a fallow system of agriculture for productivity enhancement. However, the population explosion has made fallow unrealistic, consequently leading to declined yields due to unavailability of input to complement (Adams and Mortimore, 1997). This has raised concerns about the inability of SSA inhabitants to feed their growing population in the midst of plenty (Holmen and Hyden, 2011). Per capita, food production in SSA has remained at 1961 levels and to meet the future demand for food without increases in prices requires producing about 70-100 percent additional food amidst climate change impacts and energy security concerns (Godfray *et al.,* 2010). It is against this backdrop that increased food production needs to be carried out in a sustainable manner (Middleton, 2013).

Despite challenges of producing enough food, food security concerns are officially recognised in northern Nigerian drylands as opposed to relegating it to just a 'subsistence' issue (Mortimore *et al.,* 2008). Hence, drylands have the potential to contribute to reducing the food deficits in a sustainable way as dryland inhabitants have some of the lowest carbon footprints and they can potentially contribute to carbon sequestration. This can be achieved through agricultural intensification that utilizes local labour, organic nutrient cycling and tree planting and protection (Mortimore *et al.,* 2008). Since yield per hectare is still below expectation, scientists have been concerned with increasing yields using technology that conserves the environment (Vosti and Reardon, 1997b) because good technologies will support closing the yield gap experienced by smallholders in Africa (Larson and Otsuka, 2016). Boosting agriculture of these smallholders will support about 300 million people in rural parts of Africa to escape poverty (Larson and Otsuka, 2016). However, Pretty (1997) argues that to achieve sustainability, these technologies must not be fixed but rather be adaptable to sudden occurrences, uncertainties, and changes.

Despite the potential of sustainable agriculture to offer socioeconomic and environmental benefits, there are concerns about whether it can meet the future food demand most especially in Africa (Adenle *et al.,* 2017). However, the available evidence points towards the potential of sustainable agriculture to raise yields compared to conventional agriculture (Pretty *et al.,* 2003; Graves *et al.,* 2004; Pretty *et al.,* 2006; Gowing and Palmer, 2008; Adenle *et al.,* 2017). For example, the use of good soil and water conservation practices resulted in the degraded land restoration and increased production in Central Burkina Faso by about 230 to 330 % (Pretty *et al.,* 2003). While this approach has got merit, it is argued that low input agriculture may not deliver the desirable yield due to limited land or labour to provide the amount of biomass needed to enhance fertility. Hence, the need to augment with a moderate use of external input (Gowing and Palmer, 2008).

3.2.1 Sustainability in northern Nigerian agriculture

Most Nigerian drylands are covered by sandy soils which are low in organic matter, phosphorus and nitrogen and subject to rapid degradation under intensive rainfall (Ola-Adams and Okali, 2008). In most parts of northern Nigeria, the soil is exposed to water and wind erosion because of poor vegetation and rainfall seasonality. Flexibility in ecological and economic management is key to agricultural sustainability in northern Nigerian drylands, hence any attempt at intensification could lead to loss of that flexibility (Adams and Mortimore, 1997; Adams and Mortimore, 2001). Flexibility is displayed in the use of labour, cultivar diversity (local portfolio), and use of economic plants; grazing resources, field location, and livelihood strategies.

Despite the seasonality of rainfall, when it falls, it is intense, thereby requiring means of conserving the moisture in the soil (Mortimore, 2005). Seasonality of the rainfall results in most crops being grown in the rainy season which commences in June or July (Harris, 1999). Annual rainfall amount determines the intensity of agricultural operations (Adams and Mortimore, 1997; Adams and Mortimore, 2001). Major crops grown in the northern Nigerian drylands include: cowpea, sorghum, and millet with sesame and groundnut increasingly receiving attention due to their higher commercial value. In terms of livestock, cattle are generally seen as most important, used as a source of manure and draught power. However, the place of small ruminants such as sheep and goats; poultry, donkeys and horses in supplying manure for poor farmers cannot be overemphasized (Scoones and Wolmer, 2002). Traditional practices of integrating livestock and crops in a farmstead where livestock are kept for manure collection to fertilize the field, while also collecting crop residue to feed the livestock has increasingly been neglected (Adams and Mortimore, 1997), even though it forms the bedrock of sustainable agriculture in northern Nigeria and some parts of Africa (Scoones and Wolmer, 2002). Leaving crop residue on the farm is also another means of improving fertility as livestock grazing on the field leave their droppings to fertilise the soil (Harris, 1999; Scoones and Wolmer, 2002). The environmental sustainability of the system is based on nutrient cycling and manure loading (Gabriel *et al.*, 2007).

Integrating crop and livestock is not a straightforward activity, as strategies are differentiated by agroecological conditions resulting in 'multiple pathways of change' (Scoones and Wolmer, 2002: 2). This approach is expected to encompass historical, social, institutional and ecological perspectives (Scoones and Wolmer, 2002). Integrating crop and livestock is identical to the concept of the 'circular economy in the food system' (Jurgilevich *et al.*, 2016), where consumption and discharges into the economy are controlled. A circular economy also reuses what was initially seen as a waste into a resource (Jurgilevich *et al.*, 2016). Integrating crop and livestock has been practiced over a long time as a sustainable model in the 'Kano Close-Settled Zone of Northern Nigeria' (KCSZ) (Mortimore, 2005). The KCSZ had one of the highest population densities which were positively harnessed for conserving soil. Livestock sold in this kind of system supports crop input purchase (Scoones and Wolmer, 2002).

Animal manure, especially from sheep and goat, compound sweepings, and kitchen ash, are used for maintaining soil physical properties and for providing chemical input, such as phosphorus. In addition, mulch from foliage not used and harmattan dust is used for improving soil fertility (Adams and Mortimore, 1997). Farmers without livestock, and who can afford to hire a cart, take manure from the communal heaps to their farms (Harris, 1999). However, manure is argued to be slow in delivering nutrients compared to chemical fertilisers and harmattan dust, as it 'contains complex biochemical compounds' that require time to break down (Harris, 1999). However, manure is easily available as an organic matter which helps the crop to thrive under dry spells.

Adams and Mortimore (1997) argue that population increase may have a positive impact on the environment as witnessed in the KCSZ. In the KCSZ, most of the land is under agricultural production with the farmers devoted to soil conservation through management of organic matter in the soil (Mortimore, 2005). Despite the importance of using organic means of improving fertility, FAO (2016b) suggested that in SSA, increasing nitrogen fertiliser use could potentially improve productivity and promote smallholder producers' resilience. However, this may not be applicable to other contexts such as East Asia where instead of improving production, fertiliser use causes more harm to the environment (Fixen *et al.*, 2015). Similarly, it would be interesting to understand to what extent these local approaches could meet future food requirements of drylands inhabitants as climate change bites harder. At the same time, it is important to understand off-farm factors such as the role of markets and trade.

3.2.2 Markets, trade, and food security

Most African countries suffer undernourishment and food deficiencies, with most of the population lacking sufficient access to food and basic requirements to live a healthy and active life (Luan *et al.*, 2013), with food self-sufficiency currently being lower than in the past decades. This is potentially due to population explosion which has led to more food demand than production (Luan *et al.*, 2013). Hence, the argument for the role of markets in meeting the food needs, as creating regional markets in Africa will promote agricultural production and trade. Also, some notions exist that food import rather than production could cushion the effects of food losses from global warming in poor countries. However, the challenge remains how to make export earnings from other goods sufficient to pay for the food imported (Cline, 2007).

The global food prices surge of the 2007 and 2008 portrayed the developing world and particularly Africa as constantly at risk of acute food crisis (Dupraz and Postolle, 2013). The authors argued that fears of future climatic impacts, the price surge, and food riots have led to conclusions by many observers that agricultural trade liberalisation will enhance food security, as only trade can balance the local production and supply consumers with low-priced produce. Allouche (2011) also supports this assertion stating that an increase in food security through trade was recorded between the periods 1970-1990 in other continents except for SSA.

Notwithstanding food prices surge, land grabbing and food sovereignty concerns threatened the role of global trade in ensuring food and water security. Food availability on its own does not guarantee food security because food can be available from increased production or imports supported by good agricultural policy or from food aid which exposes the recipient country to dependency and depleted foreign reserves (Davies, 2009). Figure 3.4 shows levels of import of some selected food products across the globe.

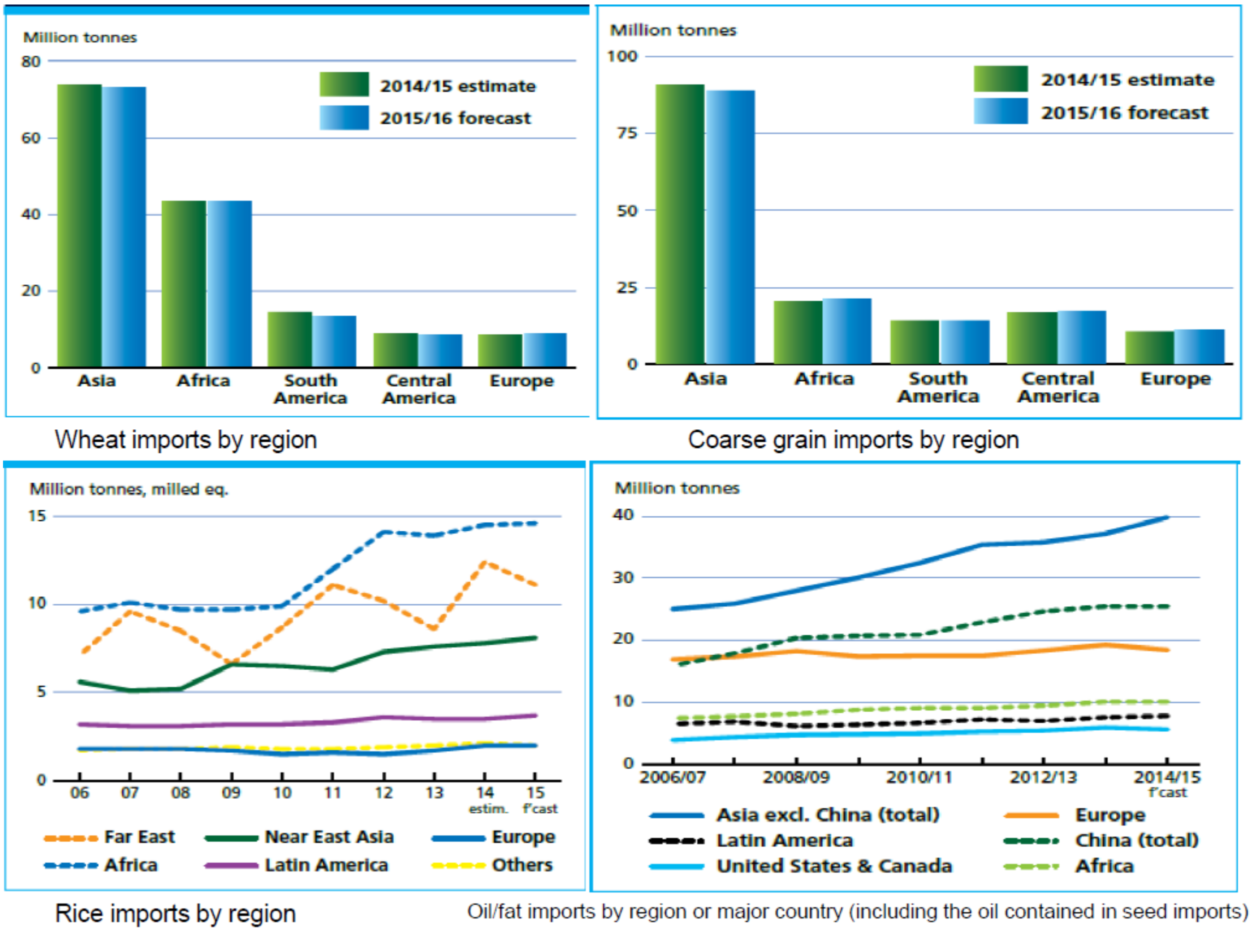


Figure 3.4 Global food imports by region.
Source: FAO. (2015a).

In contrast, agricultural liberalisation has failed to bring many gains due to various reasons such as ‘cronyism’, lack of support by government parastatals for research and extension, and lack of market opportunities (Scoones *et al.*, 2005). Consequently, this has led to heightened poverty among many and increased inequalities between the marginalised and the gainers

(Scoones *et al.*, 2005). The poor performance of neo-liberal approaches have forced the World Bank and other donors to rethink their strategies as to whether liberalisation is the means to 'pro-poor growth in the agricultural sector?' (Scoones *et al.*, 2005). However, some proponents of liberalisation assert that it is the implementation and sequencing that were problematic with other factors such as bureaucratic bottlenecks, corruption and '"cultural" impediments' being the constraint (Jayne *et al.*, 2002).
In the international market, only 19 percent of the world food produced is traded comprising 17 percent cereals and 14 percent meat (Alexandratos and Bruinsma, 2012). The idea of national self-sufficiency as the way out of global food insecurity was rejected in the UK Foresight report (2011) which later favoured the argument that globalisation of the food systems under a good law and a fully functional market could be the panacea to global food insecurity. Food imports, in this case, does not guarantee food security but a fulfilment of some bilateral food trade agreement (Davies, 2009). Hence, reliance by drylands inhabitants on the market will further expose them to more uncertainties.

Similarly, other researchers argue that food trade is not enough to solve the food security needs of dryland farmers. For instance, Hutchinson and Hermann (2008) asserted that the persistence of food insecurity in the drylands is not due to unavailability of food in the market, but rather due to low purchasing power of the poor dryland inhabitants who depend on subsistence farming that could be affected by the variability of rainfall in these areas. According to Wittman *et al*. (2010), the current neoliberal approaches to food security of 'produce or import' more from elsewhere may not change the present unequal food system that is perceived to have contributed to the degradation of the environment in the producing areas. Wittman *et al*. (2010) further argued that this strategy only succeeds in 'dumping' excess food produced to export markets at prices below the cost of production through an international trade strategy that has adverse impacts on the domestic agricultural systems by making it less competitive in the presence of highly subsidized food brought into the market (Wittman *et al*., 2010). In contrast, the UNDP and UNCCD (2011) concluded that sustainable development in the dry areas will contribute to the eradication of poverty and hunger globally through international trade in agricultural commodities of comparative advantage (Siamwalla, 1997).

Taking the case of northern Nigeria, in the past manufactured products and grain were exported to the desert areas from the savanna, kola from the forest areas taken to the north and exchanged with products such as leather, textiles, dried onion leaves, natron, livestock and shea butter. In a complex trade pattern, desert products were taken to the forest and vice versa (Porter, 1995). Similarly, trade routes were established across the Sahara to the savanna regions linking countries like Tunisia, Libya, Morocco, and the Mediterranean coast. Northern Nigerian farmers that experienced long dry seasons increasingly participated in long distance trade as a source of income. This trade pattern was supported by the Islamic religion based on its unifying philosophy and influence on methods of engagement in trade. The gains from such trade were later lost to the imposition of colonial rule through the direct establishment of boundaries and the exploitation of different markets and resources and indirectly from the influence on redistribution and population increase (Porter, 1995). To achieve food security in Nigeria, a need exists for a policy geared towards food import substitution to free foreign exchange for other critical investments.

3.2.3 Government policies for food security

Adopting sustainable agriculture could improve food productivity, reduce the use of external input such as pesticides and enhance the carbon balance using agroecological principles (Altieri and Nicholls, 2012). However, the constraint to this will be developing national and international policies that would support adoption of such sustainable means of agricultural production in both developing and the developed countries (Pretty, 2008). Current policies for food security in Nigeria, their limitations and application to drylands are reviewed next. The policy phases in Nigeria have been categorized differently. For this study, the categorization below is used to reflect the period of enactment (Table 3.1).

Table 3.1 Nigerian food security policy analysis from pre-independence to date.

Year	Policy instrument	Aims	Outcomes
Pre-independence (colonial)			
1937-1959	-Forest Policy (1937, 1945), Agricultural Policy (1946), Policy for the Marketing of Oils, Oil Seeds and Cotton (1948), Forest Policy for Western Region (1952), Agricultural Policy (1952), and Western Nigeria Policy of Agriculture and Natural Resources (1959)	Output growth: -Production of raw materials such as forest products for British industries (Ayoola, 2001) and cash crops such as cocoa, coffee, oil palm, rubber and groundnut for export.	-Plan was inconsistent (Ladan, 2013). -Policy failed due to poor institutional arrangement, goals, targets and lack of specific objectives towards attainment of the policies (Iwuchukwu and Igbokwe, 2012).
1959	Farmer settlement scheme in Western Nigeria	-Making young school levers role model modern farmers for the next generation. -Discourage rural-urban migration and train local farmers on innovative technologies. -Increased output of commodities.	-The policy failed due to inadequate institutional arrangements and poor understanding on the part of the young school levers (Iwuchukwu and Igbokwe, 2012).
Post-independence (post-colonial)			
1960-1966	The New Agricultural Policy	-Guaranteeing continuous growth in agricultural output and productivity. -Export-oriented (Western region-cocoa, Northern-groundnuts and Eastern-oil palm) (Ayoola, 2001). -Import substitution (Ayoola, 2001).	-No clear roadmaps to achieving these policies leading to their failure (Iwuchukwu and Igbokwe, 2012).

The new era (Military government) (1966-1999)			
1972	National Accelerated Food Production	-Improving efficiency of production of selected grains with incentives such as subsidy, research & credit.	-By 1973, the Agricultural Credit Bank (NACB) was established by the Nigerian Government (Rogers, 1999).
1974	Agricultural Development Programme (ADP)	-Improving efficiency of smallholder farmers through provision of modern input (Manyong *et al.*, 2005).	-Affected by the decline in oil prices leading to low agriculture growth (Manyong *et al.*, 2005). -Became less functional due to the withdrawal of funding by the World Bank (Philip *et al.*, 2009).
1976	1. Operation Feed the Nation	-Mass mobilization of high input to improve food production. -Self-sufficiency in the food supply, reform of marketing boards for optimum returns to farmers (Rogers, 1999).	-It was considered a mere campaign to grow more food which did not last long due to poor conceptualization and lack of indicators.
	2. River Basin Development Authorities	-Encouraging large scale irrigation. -It was the first major strategy for a comprehensive water resources utilization and development policy in Nigeria (Ladan, 2013).	-It was capital intensive, led to salinity and increased degradation. -It also did not perform well and so was reorganised as part of the Structural Adjustment Programme of 1986 (Ladan, 2013).
1980	Green Revolution	-Accelerating the attainment of previous programmes. -Encouraging Nigerians to go back to the farm to produce more food for sale and consumption (Manyong *et al.*, 2005). -Promotion of large-scale production (Rogers, 1999).	-Policy failed due to its focus on more mechanisation and large-scale nature with little consideration for smallholders.
1986	Directorate of Food, Roads and Rural Infrastructure	-To provide rural roads and infrastructure for the easy movement of agricultural goods to market.	-Infrastructure developed by the DFRRI were of inferior quality and poorly maintained due to corruption by programme implementers (Iwuchukwu and Igbokwe, 2012; Ladan, 2013).

1988	Agricultural Policy of Nigeria	-Food self-sufficiency and agricultural raw materials availability (Iwuchukwu and Igbokwe, 2012)	-Lack of a well-defined direction and poorly articulated policy objectives.
1989	ADP(replicated)	(see 1974)	
Return of democracy (1999-Date)			
1999 (New Agricultural Policy)	-National Economic Empowerment & Development Strategies (NEEDS) & its State (SEEDS) & Local governments (LEEDS) components.	-Poverty reduction, wealth creation, employment generation, and value reorientation. -Export growth ($3billion projected), 6 % agriculture minimum growth rate per annum (Okoro and Ujah, 2009). -95 percent food self-sufficiency. -As with Agricultural policy of Nigeria (1988) (Manyong *et al.*, 2005). -Increased raw material production. -Sustainable agricultural resources use & food security (Manyong *et al.*, 2005). -Rational use of agricultural resources.	-Poor policy coherence leading to food insecurity despite all the food security programs in place (Manyong *et al.*, 2005).
2002	National Special Programme for Food Security (NSPFS).	-Improving food production, elimination of rural poverty, strengthening research, training and extension.	-
2003	Root and Tuber Expansion Programme (RTEP)	-Economic growth, improving access to social services by the rural poor. -Address food production challenges in the rural areas (Iwuchukwu and Igbokwe, 2012).	-

2007	The 7-point Agenda of President Umar Yar'Adua	-Similar to NEEDS, later adapted into the Agricultural Transformation Agenda (ATA) (Okoro and Ujah, 2009).	-
2012	Agricultural Transformation Agenda (ATA)	-To make agriculture a business, to integrate agricultural value chain, focus on value chains where Nigeria has comparative advantage; -Create jobs (3.5 million by 2015); -Wealth creation, enhancing food security, & private sector partnership; -Increase domestic food production by 20 million metric tonnes; -Make the country self-sufficient in rice production by 2015; -Deregulate the input sectors, & reform markets (FMARD, 2016).	-Gains were recorded before the end of the Goodluck Jonathan administration as 92 percent of the target farmers for fertilizers & seeds distribution through Growth Enhancement Support Scheme (GESS) had access to input by August 2014 (World Bank, 2014). -Federal Department of Agricultural Extension was created & the Agricultural Research Network (ARCN) was reformed; -Policy could not deliver on all targets as the country still imports about $3-5 billion worth of food yearly mostly cereal (FMARD, 2016). -Consultations that led to the ATA were said to be inadequate, public awareness of the agenda also remains limited (Olomola *et al.*, 2014). -The ATA lacks an annual investment plan and institutional support is unclear (Olomola *et al.*, 2014).
2016	The Agriculture Promotion Policy (2016-2020)	-To build on the achievements of the ATA; -Building agri-business to meet domestic food security, generate exports & earn foreign exchange; -Facilitate government capacity for food security; -Sustainable use of natural resources.	-The Policy was informed by need to appraise the success & failures of the ATA & to forge a new direction for Nigerian Agricultural Sector at this time of increasing food import bill with low exports (FMARD, 2016).

3.2.4 Policy implementation

Over the years, the Nigerian Government initiated far-reaching agricultural policies covering all aspects of commodity value chains, but without proper planning on delivering on these policies holistically. Scholars argue that the constraint to ensuring efficient policy in the agricultural sector in Nigeria is mostly during its execution (Manyong *et al.,* 2005). What usually occurs is the short-term adoption of developed programmes that enhances food production in the country without any strategy for value addition and commercialization of the output (Manyong *et al.,* 2005). This leads to food losses, thereby serving as a disincentive for the farmers to grow more in the next season. Despite the growth recorded in the Nigerian agriculture sector (Sanyal and Babu, 2010), food security has eluded the country (Iwuchukwu and Igbokwe, 2012) partly due to the subsistence farming system practised (Nwafor, 2008). However, other scholars suggested that instead of smallholder-driven policies being favoured, more attention was paid to 'large-scale' commercial agriculture in Nigeria based on the colonial approach to cash crop production destined for export, more output, job creation and increased earnings (Rogers, 1999; Scoones and Wolmer, 2002).

This is further limited by poor infrastructure, poor access to credit and modern inputs, land degradation; poor research and extension and poor access to the market which has also exacerbated the conditions of rural households (Manyong *et al.,* 2005). The agricultural sector in Nigeria and Africa as a whole has suffered some neglect in the past and certain projections reveal that if the business as usual approach continues, a looming food crisis awaits the continent (Rogers, 1999; Jalloh *et al.,* 2013). In contrast to the case of the success of the Green Revolution in some South and East Asian countries, the African case is a different one due to a fall in per capita food production occasioned by environmental challenges (Rogers, 1999; Jalloh *et al.,* 2013).

The contribution of the agricultural sector to the Nigerian economy has dropped significantly over the years. In the 60s and 70s, the country was a big exporter of commodities like cotton, cocoa and groundnuts. In the same period, exports from agriculture was over 70 % of both the total GDP and export earnings, thereby making the country food self-sufficient. This contribution had significantly dropped to 30 percent of GDP and approximately 2 percent of foreign exchange earnings by 1996 (Rogers, 1999) and currently contributes around 23 % of GDP (National Bureau of Statistics, 2016).

By 1976, after the oil boom of 1970, Nigeria started to experience food shortages, thereby making it a net importer of food (Figure 3.5). Food import bill rose to $3 billion per annum over the years. Apart from the effect of the oil boom in plunging the country into this state, poor macroeconomic policies unfavourable to agriculture, including shaky foreign exchange regimes and biased investment in infrastructure, which favoured the urban more than the rural areas that produce the food consumed (Rogers, 1999), contributed to food shortages.

Figure 3.5 Percentage food import in Nigeria from 1962-2013.
Source: World Data Atlas (2017).

A need for institutional frameworks for implementing the policies previously highlighted led to the establishment in the 1980s of institutions such as the National Agricultural Extension and Research Liaison Service, National Cereal Research Institute, Veterinary Research Institute, Nigeria Institute for Oceanography and Marine Research, Forestry Research Institute of Nigeria, Cocoa Research Institute of Nigeria and Rubber Research Institute of Nigeria (Rogers, 1999). Alongside these institutions, Government established Agricultural Universities, Schools and Faculties in other conventional Universities and Polytechnics to support policy' implementation (Rogers, 1999). The Agricultural Transformation Agenda (ATA) for instance, was critical to forging a new direction in Nigerian agriculture recently which has attracted foreign direct investments in agriculture with attendant job and wealth creation (FMARD, 2016). Also, the launch of the Agriculture Promotion Policy (APP) promises stability in the Nigerian agricultural trajectory as it is one of the few times Nigeria is experiencing a continuation in Government policy.

In terms of extension in the drylands, a top-down approach to extension, where extension agents pass down message to farmers, was heavily criticised in the literature. It is argued to be expensive, not site specific, does not recognize farmer knowledge and is often rejected by smallholders (Reij and Steeds, 2003). Traditionally, increase in agricultural production in Nigeria was through expansion of cultivated area with some unsustainable growth recorded. This was in addition to the challenges of inconsistencies in policies after independence of the country and the negative effect of the oil discovery on the agricultural sector (Iwuchukwu and Igbokwe, 2012).

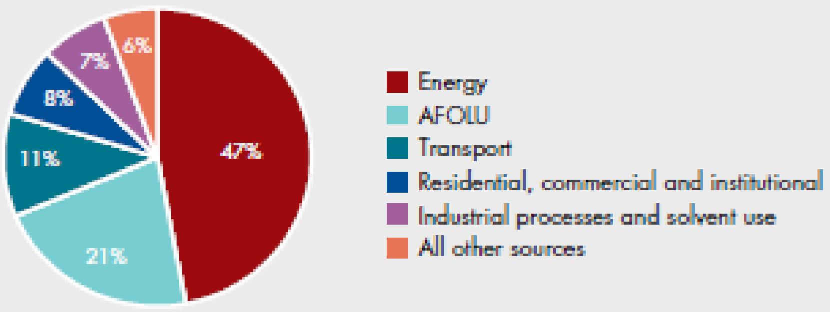
Policy initiatives to underpin extension included the establishment of the Agricultural Development Programmes (ADPs) in all states of the Federation including the Federal Capital Territory (FCT) with World Bank support to manage the Training and Visit (T & V) unified system of extension which covers livestock production and animal health, fisheries, agro-forestry, crop production and gender, mainstreaming in agriculture (NAP, 2000; Manyong *et al.*, 2005). The aim was also to disseminate improved agricultural innovations to the rural and resource poor smallholders to ensure sustainability of their production (NAP, 2000). During the T & V agricultural extension era, funding was adequate from the World Bank as salaries of staff were paid in a timely manner, project vehicles were also properly maintained, which led to adequate visits to farmers by extension agents (Philip *et al.*, 2009). Despite the strengths of the T & V model of extension, it was not without weaknesses, as technologies to transfer to farmers were inadequate due partly to poor funding of research institutes in the country and due to the time taken to certify a technology before disseminating it to farmers. Other challenges identified with the implementation of the T & V include bureaucratic bottlenecks and separation of crop from livestock extension staff, which added to the cost of extension and heightened rivalry among extension staff (Philip *et al.*, 2009).

According to Agbogo and Aja (2011), despite the well-articulated agricultural policies and strategies in Nigeria, the sector suffered lack of growth and development due to high rate of policy turn over, poor implementation of these policies and agenda designs (Oyatoye, 1984; Manyong *et al.*, 2005). Agricultural extension was left to the states to coordinate (Idachaba,

1980) with attendant poor results. The policy failures were also linked to instability in political regimes that saw different military governments, with each scrapping its predecessor's programs and policies without considering its long term positive or negative effects (Manyong *et al.*, 2005; Walkenhorst, 2007). However, this old system of state-controlled extension was abolished in the 1970s and a new system where extension staff were linked to projects and programmes was introduced (Manyong *et al.*, 2005). The following factors, as suggested by Oyatoye (1984) and Agbogo and Aja (2011), were believed to help in achieving the desired growth in the agricultural sector: good planning and a holistic implementation of plans and scientific projections, together with well-tailored policies towards smallholder needs; more attention on education and manpower improvement in agriculture; and well established nexus between research, advisory services and agricultural education. Thus far, the policies for drylands management in Nigeria might be argued to have achieved little. Hence the need for more research in this area.

3.3 Agriculture and environmental degradation management

In developing countries faced by high poverty, low agricultural productivity has been recorded with vulnerability to climate change and food insecurity. Potentials for climate change adaptation and mitigation of greenhouse gases are considered high in those areas (Lybbert and Sumner, 2012). Depending on management practices and land use, soils could act as sources or sink for carbon dioxide (Hutchinson and Herrmann, 2008). Several studies (Lal, 1999; 2004; Lal *et al.*, 2015) assert that research on the possibilities of carbon sequestration in soils of the dryland shows erosion and other degradation practices release soil carbon deposits while rehabilitation of degraded soils and change in land management practices can restore carbon (UNCCD, UNDP and UNEP, 2009). Agriculture is responsible for around 10-12% of the total global human-induced greenhouse gas (GHGs) emissions or equivalent to 6.1 Gigatons of carbon dioxide equivalent ($GtCO_2e$) per annum (AGRA, 2014). Agriculture combined with forestry and other land use account for 21% of GHG emission (Figure 3.6) (FAO, 2016b).



Notes: Emissions from energy include industries, manufacturing and fugitive emissions. AFOLU means "Agriculture, forestry and other land use". "All other sources" includes international bunkers, waste and other sources.

Figure 3.6 Shares of greenhouse gas emissions from economic sectors in 2010.
Source: FAO. (2016b).

As farmers are faced with the challenge of producing more food for society, they are also responsible for producing in a safe way to preserve the environment and maintain biodiversity services for the benefit of mankind (Burbi *et al.*, 2013). Agriculture may provide an avenue for GHGs mitigation through carbon sequestration and reduction of methane and nitrous oxide emissions through the application of Good Agricultural Practices (GAPs) (AGRA, 2014). Carbon sequestration in agricultural soils will also have the benefits of improving soil fertility and environmental quality (Srinivasarao *et al.*, 2013).

However, effective implementation of these GAPs by smallholder farmers might be faced with financial and other constraints (FAO, 2009; Burbi *et al.*, 2013). Hence, the need to assist farmers financially and technically to have the capacity to adapt is important (FAO, 2009). The assistance should be locally and not nationally targeted, based on local conditions and needs (Makhado *et al.*, 2014). Payments for sequestered carbon through a financial model could offer a leeway in influencing actions that will improve the livelihood of West African smallholders and at the same time the global environment if the cost and the benefits of adopting good management practices together with the potential for GHGs mitigation are known (Lipper *et al.*, 2010). Agricultural emissions are not accounted for in the Reduced Emissions from Deforestation and Forest Degradation (REDD); however, the REDD+ is expected to account for agricultural activities through the agroforestry component (Mbow *et al.*, 2012).

Rosenstock *et al.* (2013) argued that data on GHGs emission on smallholder agriculture in developing countries are not well documented or in most cases are lacking. They further argued that the unavailability of data poses a challenge in transitioning to a low-carbon agricultural economy. Hence, emissions reduction could be achieved without necessarily cutting down production, as incentives to reduce water and fertiliser use can be very efficient (Foresight, 2011). It is possible to achieve the multiple visions of food security, greenhouse gas mitigation, adaptation and development (Figure 3.7) if synergies are harnessed and trade-offs reduced (FAO, 2009).

Controlling soil degradation has been the focus in improving the loss in crop productivity in the drylands of West Africa (Bayala *et al.*, 2012). In their study of cereals responses to conservation agricultural practices, Bayala *et al.* (2012) found that compared to the control higher yield increases were recorded under green manure and mulching while coppicing of trees and parklands gave less yield. On the average yield increases were higher under the six conservation practices considered in the study for maize, millet, and sorghum planted on sites with low to medium productivity. Mulching did well under less than 600 mm rainfall (Bayala *et al.*, 2012). Other researchers (e.g. Gowing and Palmer, 2008; Warren *et al.*, 2001) suggest that improving rain-fed agricultural systems without negative impact on the environmental services will solve the hunger and poverty conditions of sub-Saharan Africa.

Food Security potential	Food Security potential: **High** Carbon Sequestration Potential: **Low** • Expand cropping on marginal lands • Expand energy-intensive irrigation • Expand energy-intensive mechanised systems	Food Security potential: **High** Carbon Sequestration Potential: **High** • Restore degraded land • Expand low energy-intensive irrigation • Change from bare to improved fallow • Agroforestry options that increase food or incomes • Conservation tillage and residue mgmt, limited trade-offs with livestock • Improved soil nutrient management
	Food Security potential: **Low** Carbon Sequestration Potential: **Low** • Bare fallow • Continuous cropping without the use of organic or inorganic fertilization • Slope ploughing • Over-grazing	Food Security potential: **Low** Carbon Sequestration Potential: **High** • Reforestation/afforestation • Restore/maintain organic soils • Expand bio-fuel production • Agroforestry options that yield limited food or income benefits • Conservation tillage and residue mgmt., large trade-offs with livestock
		Carbon Sequestration Potential

Figure 3.7 Examples of Potential Synergies and Trade-Offs.

Source: FAO (2009). Mgmt.= management.

3.3.1 Policies and International Conventions for drylands management in Nigeria

The Nigerian Government enacted policies and subscribed to International treaties and conventions as parties, due to the apparently degraded condition of the drylands region, to tackle this menace from the root cause. Among these conventions were the United Nations Convention to Combat Desertification (UNCCD).

i. The UNCCD

During the Rio Earth Summit in 1992, loss of biodiversity, climate change and desertification were recognised as key constraints to attaining Sustainable Development. This led to the establishment of the UNCCD in 1994 (referred to as 'The Convention') that is a legally binding agreement signed by 195 parties including Nigeria which links development and environment to sustainable land management (UNCCD, 2016). The convention tackles the drylands of the World which comprises the arid, semi-arid and the dry sub-humid home to people living in a very vulnerable ecosystem. Drylands people are engaged through a bottom-up participatory approach to solve their environmental challenges and to reduce drought effects (UNCCD, 2016). The convention enables cooperation between the developing and developed countries in the transfer of technology and knowledge sharing to enhance sustainable land management. The efficacy of the 'international convention model' in solving drylands challenges has been questioned by critics due to its top-down approach (e.g. Toulmin and Brock, 2016: 44).

Due to the nexus among climate, biodiversity, and land, the convention sought collaborations with the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD) which are also Rio Conventions to ensure efficient natural resources use in an integrated way (UNCCD, 2016). As part of the obligation of signatory parties to this convention, Governments were required to develop National Action Plans in line with strategies to achieve the convention's goals. This led to the development of the National Action Programme to combat desertification by the Nigerian Government.

ii. The NAP

Nigeria ratified the UNCCD in 1997 leading to the development of its action plan (NAP) in the year 2000 as its national strategy for implementing the convention. This NAP contained important activities to be implemented holistically to remedy the problems of desertification in Nigeria. Human population pressure on the marginal lands of the northernmost part of Nigeria had a significant effect on the environment. This led to desertification and was further worsened through attempts by inhabitants of the dry areas to exploit the environmental resources amidst increasing drought (NAP, 2000) to feed their poor families. Attempts by the Nigerian government to mitigate the desertification challenge recorded little success in the past, however, with the development of the NAP, the government became optimistic that a holistic approach to tackling this menace while ensuring food security and environmental conservation was found (NAP, 2000).

Overall, Nigeria focussed its policies around protecting the environment with emphasis on the challenges of desertification and drought which influenced the direction of national policies, legislative and institutional frameworks, partnership building and sectoral programmes in the past and present towards tackling these challenges (NAP, 2000). As contained in the NAP, the Nigerian environmental policies aimed at achieving food security through sustainable agricultural practices advocacy, participatory water resources management, maintaining awareness on causes and effects of desertification and the limitations of the UNCCD. Additionally, the government focused on supporting state and national institutions to effectively control desertification and drought; promoting community and individual participation in reforestation and afforestation using drought and pest tolerant economic trees; establishing drought early warning systems. Others include: to stimulate international partnership around research and environmentally friendly technology transfer; take record of degraded and non-degraded lands to avoid future degradation, taking a holistic approach to addressing all aspects of drought and desertification, establishment, reviewing and enforcement of grazing reserves and cattle routes (NAP, 2000) to curb farmer-pastoralist conflicts. To achieve this, legal backings and institutions were required, leading to the passage of legislations and establishment of institutions to support government's aspirations in that direction.

iii. Legislative and Institutional Framework

The Federal Government of Nigeria by the Decree 58 of 1988 established the Federal Environmental Protection Agency (FEPA), which was widely acclaimed as the most significant initiative taken by Government towards tackling the multi-dimensional environmental challenges facing Nigeria (NAP, 2000). The FEPA got more legal support through the Decree 59 of 1989, which empowered it to sanction bodies that did not comply with the National Environmental Policy, which made FEPA the highest coordinating institution on all environmental protection related matters in Nigeria. More so, to have effect across the country, state and local government environmental protection agencies were established in the 36 states including the Federal Capital Territory (FCT) and 774 local government areas with the mandate to address all environmental challenges at those levels although most states have their laws and edicts on environmental protection such as edicts on deforestation and bush burning.

The FEPA became the secretariat for the implementation of the NAP through a National Co-ordinating Committee to combat desertification with representations across Ministries, Agencies, NGOs and related research Institutes saddled with the responsibility of coordinating the implementation strategies of the Convention. Other institutions also established to support the FEPA include the Department of Drought and Desertification Amelioration in the Federal Ministry of Environment for effective coordination and support of the existing institutional plan for the implementation of the Convention (NAP, 2000). However, in 1999 FEPA was merged with other Departments to form the new Ministry of Environment, but with no legislative backing on environmental law enforcement which led to the creation of the National Environmental Standards and Regulations Enforcement agency (NESREA) under the Ministry of Environment (NESREA, 2016). By the NESREA Act 2007, the FEPA Act was repealed, making NESREA the successor Agency. To further decentralise the NAP, sectoral programmes for the different sectors were created to support the implementation processes.

iv. Water resources sector

River Basin Development Authorities (RBDAs) were established under the Federal Ministry of Water Resources to promote sustainable water resource utilisation in drylands through the development of irrigation infrastructures such as dam constructions and watercourse diversion from rivers, provision of rangeland watering points, water supplies to communities and underground water exploitation. Five RBDAs were located in the semi-arid areas of Nigeria which include; Upper Benue, Niger River, Chad Basin, Sokoto-Rima and Hadejia-Jama'are Development Authorities (NAP, 2000). This approach was a broad-based-one size fits all approach which failed to meet the needs of productivity improvement amongst smallholder farmers. It also resulted in the loss of fadama areas (Adams, 1991; Nichol, 1991).

v. Forest development

The Federal government of Nigeria in 1976 created the Arid Zone Afforestation Project to control desertification through the establishment of shelterbelts, woodlots and windbreaks. Between 1978 and 1984 more than 10 million tree seedlings were raised annually which led to the establishment of about 3,680 hectares of woodlots, 70 tree nurseries, 150 kilometres of shelterbelts and vocational schools for forestry with 24 boreholes dug for water supply (NAP, 2000). The forestry programme also targeted extension and farmer participation with a focus on land use policy, sand dune fixation, bush fire prevention, silvopastoral systems, fuel energy and mass tree planting campaign. Other sectoral initiatives included the energy resources initiative.

vi. Energy resources initiative

Despite the abundant renewable energy potentials in the drylands, households rely heavily on fuelwood and other fossil fuels. Fuelwood harvesting by these households for home use and sale has been linked to exacerbating desertification in the dry areas of Nigeria (NAP, 2000). As a result, the Nigerian Federal Government set up the following programmes under the Energy Commission of Nigeria (ECN) to optimise the utilisation of renewable resources in those areas to ameliorate desertification occasioned by fuelwood harvesting:

- Biomass and biogas utilisation projects;
- Solar photovoltaic electrification projects for remote rural areas;
- Training on renewable energy technology.

These were informed by the Nigerian National Policy Guidelines on Energy (NAP, 2000).

vii. Integrated Poverty Alleviation Programme

The relationship between poverty and resource degradation has been a subject of debate in the literature (Vosti and Reardon, 1997b). Despite the lack of direct causal link, poverty reduction was argued to be essential to environmental management as the primary motivation for the action of the poor is their survival (De Haen, 1997). Given that the role of poverty alleviation in controlling desertification has been understood, the Nigerian government set up some poverty reduction programmes in the arid regions with their aims and other highlights presented (Table 3.1).

Table 3.2 Aims and some highlights of the integrated poverty reduction programmes.

Programme	Aims and highlights
Northeast Arid Zone Development Programme (NEAZDP).	-Funded by the Nigerian government with EU support. -Started in 1990 aimed at motivating and assisting rural dwellers to improve their living standards through efficient use and management of resources. -Total coverage of 25,000 sq km. -Water resources management and development (irrigation inclusive). -Supply of micro-credit for out of season economic activities, small cottage industries and livestock fattening support. -Provision of rural banking and promotion of ox-plough for agricultural activities and land preparation.
Federal Ministry of Environment/ University of Maiduguri (FMEEN/UNIMAID) linkage model village project.	-Model village project initiated in 1995 at Sabon garin Nangere, Yobe state. -Establishment of community woodlots, the supply of energy efficient wood stoves, roadside tree planting, biogas supply for home use, provision of solar-powered motorised boreholes in the community and provision of Ventilated Improved Pit (VIP) toilets. -Although it currently faces financial setbacks, it has recorded enormous success which merits replication in other Nigerian drylands.
Katsina State Agricultural and Community Development Project (KSACDP).	-Initiated by IFAD to intensify and speed up Nigerian drylands' rural development. -Aimed to improve resource management through a participatory approach by 'in-group' credit mobilisation and cooperative action on combating degradation that affects the agricultural land. -Farming practices were improved, and groups of poor and landless female-headed households were handed with investments for community development and off-farm income generation.
Sokoto State Environmental Protection Programme (SEPP) at state levels (NAP, 2000).	-Covers around 17,500 sq km of the north-eastern part of Sokoto state. -To improve resource utilisation for environmental protection and sustainable growth in the long-term. -Funded by the Federal and Sokoto state governments and support from EU. -It encompasses livestock & range management, infrastructure development in rural areas, afforestation, irrigation, adult literacy and women development. -To be implemented through community mobilisation, awareness and development. -Greater success achieved through improvement of living standards of inhabitants of project area.

Source: NAP (2000).

3.3.2 Nigerian National Agricultural Resilience Framework (NARF)

As part of the drive towards food security in Nigeria, the Federal Ministry of Agriculture and Rural Development (FMARD, 2013) commissioned experts from across the globe to develop a national resilience framework to promote food and nutrition security amid climate shocks and stresses. To support this drive, the government developed far-reaching policies ranging from the Growth Enhancement Support Scheme (GESS) (for effective distribution of seeds using mobile phones), the Nigerian Incentive-based Risk Sharing for Agricultural Lending (NIRSAL) to reduce risk to Banks of lending to agribusinesses and farmers. Flood and drought early warning systems were advocated for resilience promotion. Consequently, the Central Bank of Nigeria 'established a $350 million risk sharing facility' to leverage a $3.5 billion loan from banks to farmers. Policies for improving water management were also promoted by increasing the area under irrigation through the distribution of subsidised motorised pumps (targeted more at women), alternative energy sources to rural areas to power the motorised pumps and provision of loans to communities for watershed management.

The NARF argues that national food security drives should incorporate conservation of the natural resources as a key priority. Integrated approaches such as the use of SLM could potentially yield significant environmental benefits, enhance farmers' resilience to climate change and variability. Broadly, the NARF strategic objectives were as follows (FMARD, 2013: 32):

- Strengthening the overall policy/institutional framework for improved resilience and adaptation to climate variability and change in the agricultural sector, including planning and implementation, systems for resource mobilization, and effective project monitoring and evaluation.
- Evaluation and introduction of risk transfer and risk management strategies (e.g., improved seasonal and real-time weather forecasts, insurance-based risk mitigation options etc.) into the agricultural sector and widespread deployment of same through communication technologies, including mobile phones.
- Improving productivity through training community and grass root farmers on land and water management strategies (e.g., irrigation farming, water harvesting, soil fertility enhancement and erosion control etc.) improved farming practices and using policy instruments such as economic incentives, regulations and communication.

- Reinforcing existing social safety nets through support systems that reduce vulnerability and improve livelihood conditions for the vulnerable, especially women and children.
- Improving farming systems research capacity within the National Agricultural Research System (NARS) to enable and support the implementation of climate friendly agriculture in Nigeria.
- Revamping extension services, including building new capacity for evidence-based assessment and management of climate risk for resilience in the agriculture sector.

3.3.3 Environmental Policy implementation

Knowledge about the direction of sustainable agriculture and development is still sketchy as knowledge development will hinge on future actions, processes, analysis and deliberations that are iterative in a dynamic and varied food systems that advocate for policies that underpin social objectives that include poverty reduction, socio-economic, political and ecological dynamics, while supporting flexibility in adapting to uncertainties (Thompson and Scoones, 2009). Despite the policies enacted for sustainable farming in Nigeria, implementation has been flawed with lack of political will to implement and lack of continuity in government policies and programmes which have hindered agricultural development (Rogers, 1999).

Most dryland countries have sustainable land management policies but suffer from poor implementation or no implementation at all (IUCN, 2015). In 2007, African countries' Presidents with the support of the African Union agreed to initiate a fund for the implementation of the Great Green Wall Programme (GGWP) that entails planting tree walls (15 km wide and 7,775 km long from Dakar to Djibouti covering 11 countries) across the East and West through the deserts in Africa to combat environmental degradation, ensure Sustainable Land Management, restore drylands, conserve biodiversity, mitigate climate change impact and improve agricultural productivity in SSA (FRN, 2012). However, the GGWP was criticised for being modelled around 'control' rather than empowerment of dryland inhabitants. Also, recent studies in China also criticised the GGWP concept for being only tree based despite including other vegetation types and shrubs and also due to its aggressive approach to environmental management making it difficult for desertification to be tackled holistically (Jiang, 2016). Also, the complex structure of the GGWP makes it difficult to assess the success of the initiative in tackling environmental challenges and sustainable natural resource use and management by affected rural communities (Toulmin and Brock, 2016). Policy inconsistencies, instability and poor implementation and 'weak institutional framework for policy coordination' among others have been the bane of agricultural development in Nigeria (Manyong *et al.,* 2005). The challenges facing agriculture in Nigeria are multi-dimensional and multi-faceted. Hence, programmes and policies to address these challenges must also be multi-dimensional in approach (Rogers, 1999).

3.4 Research and Development for Sustainable Agricultural innovations

A consensus exists that agricultural research investments yield good returns (Lybbert and Sumner, 2012). However, investments in African agricultural research has dropped significantly (Reij and Steeds, 2003; World Bank, 2008). This was suggested to be due to several reasons such as lack of capacity to invest and poor lending to agriculture in developing countries (Beddington *et al.,* 2012). In Nigeria, agricultural research has been identified as the pivot of national food security and economic growth with the government having numerous institutions and organisations saddled with the responsibility of doing research (FMARD, 2016). In the 1970s, reforms around agricultural research systems focussed on creating an institutional apparatus to nationally coordinate agricultural research and to establish strong linkages among research, extension and farmers (Manyong *et al.,* 2005). Together with other international centres for agricultural research in the country, the National Agricultural Research System (NARS) has failed to drive 'sustainable agricultural growth' that will lead to national food security, create employment and wealth and launch Nigeria as a big player in the international food markets (FMARD, 2016).

Tropical agricultural research on issues ranging from timely and proper sowing and tillage, new varieties of crops, improved fertilisers and pesticides and mechanisation have produced new technologies that led to improvements in farmers' production in other regions of the globe (Van Duivenbooden *et al.,* 2000). This has been the broad objective of agricultural research policies for technologies development that are well suited to the Nigerian climate (Manyong *et al.,* 2005). The innovation developed, and their effective dissemination will greatly influence farmers' mitigation and adaptation strategies to climatic variability (Lybbert and Sumner, 2012) at the same time meet food security objectives if implemented. Previous yield increases were from non-renewable energy uses which necessitate urgent action on mitigating GHGs from the agriculture sector (Long *et al.,* 2015). Therefore, the need for innovations to supply these future food demands while ensuring poverty reduction and resources conservation under sustainable intensification (Reardon and Vosti, 1997a) cannot be over-emphasized.

Tambo and Abdoulaye (2012) in their study of climate change and agricultural technology adoption taking the case of drought tolerant maize variety in rural Nigeria found that new agricultural technologies are essential in supporting continuous food production by smallholder farmers in a changing climate. For these technologies to be widely adapted by farmers at a greater scale, complementary support will be needed. Pretty *et al*. (2010) also support this assertion as they advocated for technology development such as drought-resistant crop varieties as a means of bridging the gap between increased food production and environmental stewardship. The success of the Machakos in Kenya on the use of early maturing and drought resistant maize to escape drought is another case in point (Mortimore and Tiffen, 1995).

Funding for agricultural research by the National government in Nigeria has been ongoing with some instability in the funding experienced since the 1980s with private funding been very negligible (Philip *et al.,* 2009). This is amidst the apparent increase in research funding recorded (Figure 3.8). Continuous under-funding of research could lead to un-improvement of agricultural technologies with consequence for loss of farm income, rural jobs, reduced food security, diminished poverty reduction efforts, food prices increase, reduced economic growth and agricultural productivity in the rural areas (Philip *et al.,* 2009; Beddington *et al.,* 2012).

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Figure 3.8 Agricultural R&D Spending adjusted for inflation, 1981-2008.
Source: Flaherty *et al.* (2010).

Despite the usefulness of external source of agricultural research for innovative technologies, it is not the only source of innovations as smallholder farmers have evolved with their cost effective new practices that need to be promoted (Reij and Steeds, 2003). However, a good understanding of the innovation and the environment is essential to a successful technology adoption. In Burkina Faso, farmers invested in the improvement of degraded lands by introducing innovations in soil and water conservation, agroforestry and other soil fertility management techniques (Hutchinson and Hermann, 2008). For agriculture to thrive, Sustainable resource management must be top on agricultural research and development agenda in sub-Saharan Africa (Sangina *et al.,* 2003).

3.4.1 Land and water resources management

Apart from water management, improving rain-fed agriculture calls for investments in crop, soil and farm management (Pathak *et al.,* 2009). However, traditional tenure has limited the level of investment in land and sustainable agricultural intensification (Tabor, 1995). Rain-fed agriculture will play a key role in feeding the world population (de Fraiture *et al.,* 2009; World Bank, 2003) as eighty percent of agricultural land worldwide is rainfall dependent (Map 3.1) which is low yielding with a high attendant on-farm water loss (Rockström *et al.,* 2003; Rockström *et al.,* 2010). Uncertainties surround the validity of the cause of the water problem in dry areas; whether due to physical shortages or poor management and lack of human capacity to manage available water efficiently (Rockström, 2001; Rockström and Karlberg, 2009).

Hanjra and Qureshi (2010) assert that water unavailability could lower production thereby affecting food security. Thomas (2008b) also agrees that in dryland areas, the challenge to agricultural production is not land but water. As such, improving water use efficiency and reducing water demand should be the major focus of climate change adaptive strategies. The effects of fertiliser application to soils are also limited by soil erosion and low rainfall. Hence, soil and water conservation must be achieved for fertility measures to have any results on the soil (Tabor, 1995).

Map 3. 1 Areas dependent on rain-fed agriculture vs irrigation globally.
Source: IWMI (2007).

Some studies (Hanjra and Qureshi, 2010; Slegers and Stroosnijder, 2008) suggested that to tackle the challenges of water scarcity and food security of smallholder agriculture will require improving water use efficiency that will lead to '*more crop per drop of water and energy*'. Investments in efficient management of agricultural soils and water (through water harvesting technologies for additional irrigation) in drylands (Øygard *et al.,* 1999) to cover yield gaps and to reduce risks of crop failure induced by dry spells cannot be over-emphasized (Rockström *et al.,* 2010). Using such techniques that do not result in environmental degradation have been proven to be promising (Dile *et al.,* 2013; Russo *et al.,* 2014).

Improvements in agricultural water use will reduce global water use as agriculture is the single largest sector that consumes more water globally (Russo *et al.*, 2014) and specifically in SSA (AGRA, 2014). There is evidence that agricultural water harvesting techniques yield satisfactory results throughout the Sahel; though their adoption has not been very widespread due to certain constraints (Tabor, 1995). Studies that reviewed successes of projects in SSA linked these to technology and institutional development as the main drivers of the successes (Reij and Smaling, 2008). In dry areas where rain falls in few concentrated showers, it is important to time agricultural practices as water and nutrient requirements of crops differ at different stages of their development (Slegers and Stroosnijder, 2008). Some soil and water resource management practices are explored.

i. **Conservation Agriculture:**

Conservation agriculture (CA) is one of the technologies advocated for managing soil degradation and poor productivity, for food security in SSA dry areas (Baudron *et al.*, 2012). Contrarily, Giller *et al.* (2009) argued that no evidence suggests the widespread uptake of CA in those countries except for a few pockets of adoption in Ghana, Zambia and South Africa. Furthermore, the barriers to adoption could stem from several factors such as labour demand for weeding, poor access to external input; other uses of crop residue for animal feeding, fuel and construction material (Giller *et al.*, 2009; Mason *et al.*, 2015); and poor adaptation to local conditions (Tittonell *et al.*, 2012). Nana *et al*. (2014) also assert that existing CA practices in West and Central Africa are not implemented with the aim to sustainably manage land, rather they are opportunistic practices that come because of socio-economic challenges. Arguably, opportunities exist for the implementation of some CA innovations in semi-arid zones despite the challenges faced in these areas (Nana *et al.*, 2014).

Conservation through terracing has since been accepted as part of good farming as it saves both moisture and soil in low and variable rainfall conditions in drylands of Africa (Mortimore and Tiffen, 1995). Rockström (2001) opines that conservation tillage (CT) which discourages soil inversion practices using ploughs and encourages the use of a set of tillage practices such as mulching could be said to be the most favourable less cost means of improving production systems available; as ploughing in the hot tropics could result in a significant effect on precipitation distribution and future soil fertility leading to formation of soil crust, fertility loss, reduced soil infiltration and poor water holding capacity. For CA to be fully embraced, it must be designed to fit the local conditions by selecting CA techniques that will perform well considering the topographies of the area to be implemented (Nana *et al*., 2014).

ii. **Sustainable Intensification (SI):**

The growing prosperity and population explosion in the world will lead to more pressure on the agricultural resources of the world and yields from crop and livestock productivity will have to improve to meet this growing demand which will result in increasing environmental degradation (Struik *et al.,* 2014). It is possible to protect the habitat while increasing yield through sustainable intensification; another way to achieve this is by reducing food waste and over demand for land intensive crops which is equivalent to increasing yields (Phalan *et al.,* 2011). Loos *et al*. (2014) argued that the definition of sustainable intensification by Phalan *et al.* (2011) as a process that improves yields with less environmental footprint and without increasing the current agricultural land area lacks merit in the context of the conventional principles that define sustainability. Therefore, sustainable intensification may not achieve the goal of enhancing food security if it goes by the emphasis on food production against considering other drivers of food security. Struik *et al.* (2014) further supported this notion arguing that the scope of SI that projects production of more food from fewer resources as the panacea to food security is not all encompassing as it masks trade-offs involved in adopting this approach to sustainability. Therefore, a shift to "*ecological intensification*" where increasing agricultural output is linked to "*ecological processes in agro-ecosystems*" was proposed.

iii. **Agro-ecology**

The application of agro-ecological principles has been considered at different scales in the literature ranging from field or plot scale, farm scale and farming system scale (Wezel *et al.,* 2009). Similarly, agroecology is defined differently by the key promoters of the concept. For example, Tittonell argues that agroecology is a knowledge intensive concept that thrives through integration of different knowledge epistems such as scientific knowledge, farmer practical knowledge and farmer movements (Tittonell *et al.*, 2012; Tittonell 2014). On the other hand, several studies suggest that agroecology entails only the promotion of farmers' autonomy, sovereignty, socio-political movements and reliance on the family farms as farming models (Altieri, 2010; Altieri and Nicholls, 2012; Gleissman, 2013; Rosset and Altieri, 2017). For the purpose of this study, the definition of agroecology advocated by Tittonell *et al.* (2012)

is employed. Agroecology has been said to be a component of ecological intensification (Tittonell, 2014) and defined by Francis *et al.* (2003) as the study of the entire food system that encompasses both the social and natural sciences that underscore systems philosophy and ecological thinking. Agro-ecology promotes biodiversity, conserves water, integrates crop and livestock on the farm enterprise, controls soil erosion and recycles plant nutrients (Thompson and Scoones, 2009). Similarly, agro-ecological intensification that takes into cognisance environmental stewardship is important as Carolan (2013, pg.127) argues that huge 'ecological footprints' cannot be sustained and need to be curtailed as "the old moral economy was predicated upon care first and economics second" (Carolan 2013. pg. 170). Other researchers (Altieri and Nicholls, 2012) support this assertion suggesting that an alternative to the industrial agricultural development paradigm is needed that supports ecological and biodiversity conservation. They stated that this model has been tried by about 75 percent of smallholder farmers across the world which is responsible for about 50 percent of global food consumed compared to the industrial agricultural food system that lacks any elements of sustainability (economic, social and environment) (Gliessman, 2013).

This system precludes the use of external inputs (such as pesticides and chemical fertilisers in monocultures) and in its place, natural means of biological control and soil fertility management are employed which has overwhelming evidence of increasing productivity sustainably (Altieri and Nicholls, 2012). Agroecological farming offers more potential for sustainable yields to resource-scarce farmers thereby ensuring their food security (Altieri and Nicholls, 2012). Notwithstanding these potentials, agro-ecological farming practices dissemination and adoption have been constrained by many factors such as lack of information around policy by extension and farmers, market failure, infrastructural deficits and poor land tenure (Altieri and Nicholls, 2012). Agroecological systems should be targeted towards increasing the productivity of the poor, conserving the natural resources, employment creation and provision of access to local output and input markets (Altieri, 2010).

iv. **Biotechnology:**

Other researchers also argued for the adoption of biotechnology as a solution to food insecurity (Zilberman *et al.,* 2014). Proponents of biotechnology argue the use of biotechnology will improve the environment, enhance food security; heal or eliminate disease and lead to a healthy and prosperous society (Phillips, 2002). However, critics disagree, arguing that it will rather increase food insecurity, expose the environment to risks, weaken the ecological system of farming (Altieri and Nicholls, 2012), endanger human health and subsequently impoverish society itself (Phillips, 2002). Altieri and Nichols (2012) further argued that genetically modified (GM) crops developed for example with pest resistance traits and 'single control mechanism' have failed to control pest but rather led to more hardy pests that will warrant more use of pesticides. In Nigeria however, safety concerns, funding and poor extension to increase awareness on the potential of biotechnology have hindered the uptake of this technology (Davies, 2009).

v. **Agroforestry:**

This is a low-cost means of ensuring sustainable agriculture and supports the restoration of smallholder productive capacity for resilience to climate change (Kidane, 2010), food security (Mbow *et al.,* 2014), as a source of livestock feed, fruits and income (Bayala *et al.,* 2014) and soil fertility management. It is argued that agroforestry which includes field windbreaks, alley cropping, silvo-pastures riparian buffers and forest farming; increases organic carbon in the soils (FAO, 2009). Despite its resilience building to climate change, agroforestry conflicts with the requirement of additional land to produce more food, fuel and fibre per unit area of land. For example, poor smallholders in western Kenya rejected agroforestry as it conflicts with their immediate goal of household food security, and due to risks of investing their labour and time on technologies with uncertainties surrounding its long-term benefits (Jerneck and Olsson, 2008). Hence, the need to plant trees that are food sources or provide ecosystem services themselves in the practice. *Faidherbia albida has* potentials of improving crop yields and to protect crops from winds and land from erosion in an agroforestry set up (Altieri and Nicholls, 2012). Tree biomass and the nitrogen fixation abilities help in soil fertility management (Venkateswarlu *et al.,* 2013) and shade tree cover shields plants from climate extremes and soil water fluctuations (Altieri, 2010).

vi. **Mulching and cover cropping:**

This is the application of porous organic or mineral matter to the soil surface which includes aged manure, compost, wood shavings and straw (Lancaster, 2010). Mulching and cover cropping supports water conservation and makes nutrients to be readily available to crops (Altieri, 2010). It also increases infiltration rate, improves soil fertility, reduces evaporation, limits soil erosion and enhances weed suppression (Lancaster, 2010). In addition to this, production and retention of biomass also help in avoiding soil compaction and crusting (Baudron *et al.*, 2012). Despite these benefits, results from a study of Conservation Agriculture (CA) in semi-arid Zimbabwe showed that farmers perceived mulching introduces pests and weed seeds in the farm (Baudron *et al.*, 2012).

vii. **Water harvesting for agriculture:**

Oweis *et al.* (2012) define water harvesting (WH) as the practice or process of saving natural rainfall from catchments for important uses. Inefficient utilization of water as opposed to unavailability of water for agricultural production, warranted the development of techniques for collecting water at the macro- and micro-levels. The micro- methods which comprise 'in-situ' and 'ex-situ' are important for agricultural uses. Some selected water harvesting techniques that have worked elsewhere are presented (Table 3.3).

Water harvesting systems have three components namely; a catchment area (land, rooftop, courtyard), secondly, a storage facility (jars, ponds, reservoirs, soil profile, under/over-ground cisterns and aquifers) (Levario, 2007), and thirdly, a target (user-plant, animal and people) (Oweis *et al.,* 2012). Despite the advantages of water harvesting, they also come with some disadvantages, which include soil erosion from slopes cleared for runoff, conflicts between downstream and upstream users of a watershed and conflict between herdsmen and farmers in drylands competing for water (Oweis *et al.,* 2012).

Table 3.3 **Some selected water harvesting techniques.**

Practice	**Description**	**Benefits**	**Location** (in-situ/ex-situ)	**Reference**
Zai pit	Planting pit with diameter 20-40 cm & depth 10-20 cm dug during the dry season (up to 25,000 pits/ha) pits used for growing plants	Zai pits conserve soil & water, and control erosion on already degraded soils.	In-situ (Burkina Faso & Niger)	(Oweis *et al.* 2012), AGRA, 2014.
Run-off farming	Hillsides are cleared, smoothed to induce runoff directed to fields.	Supports irrigation in dry areas.	Ex-situ (Northern Libya)	(Oweis *et al.* 2012).
Rooftop water harvesting	Making drains using PVC pipes or non- corrosive materials to collect rain from house roofs.	Garden irrigation and drinking.	Ex-situ (Mediterranean region)	(Oweis *et al.* 2012).
Inter-row water harvesting ridges	Bunds and ridges made on flat land or gentle slopes.	Concentrating available water on cropped strip.	In situ	(Oweis *et al.* 2012).
Contour ridges	Made with packed soil & reinforced with stones & ridges constructed on slopes from 1-50%.	Supports production of sorghum, millet, cowpea and beans.	Semi-arid tropics	(Oweis *et al.* 2012).
Mulch	Apply porous organic or mineral material to soil surface (compost, aged manure, wood shavings, straw, and gravel).	Increased infiltration rate, improved soil fertility, reduce evaporation loss, limit soil erosion, weed suppression.	In situ	(Lancaster, 2010)
Vegetation	Planting of vegetation cover in the target area.	Increased infiltration, erosion control, water storage, food source.	In situ	(Lancaster, 2010)

3.5 A Conceptual Framework for promoting sustainability and resilience of drylands food system-Science informing practice

Producing food to feed the global population in the era of climate change is not a straightforward activity as it requires understanding the underlying issues surrounding agricultural yield improvements. It must be holistic in approach while encompassing all the problems in the food system. In SSA, uptake of scientific knowledge for long-term adaptation to climate change and resilience enhancement is limited (Jones *et al.*, 2014). To uptake a new practice, it is important to understand the scientific evidence of the benefits of such a practice. Based on the foregoing, a conceptual framework that ensures food is produced in an ecologically friendly way amid climate change is needed. It is against this backdrop that this section argues for the deployment of good agricultural practices (GAPs) as tools for promoting drylands food systems' resilience and consequently food security and environmental quality based on integrating technical, policy and institutional approaches (Figure 3.9).

Figure 3.9 Strategies for managing drought and enhancing resilience.
Source: AGRA (2016).

Hence, the need to review the scientific evidence around GAPs and the benefits derivable from the application of these practices. It is not enough to highlight the benefits of these GAPs but rather findings from this study should prove the benefits or not of GAPs after testing and where applicable modified to the specific conditions of a community.

3.5.1 Good agricultural practices (GAPs)

This concept has been interpreted differently by different people at various times. GAPs are also referred to as good agronomic practices, best practices in agriculture or best management practices (BMPs) (Ingram, 2008). Some selected GAPs for tropical drylands management and their benefits are listed in table 3.4. For a comprehensive list, see appendix 1.

The advocacy for the adoption of scientifically proven GAPs was due to the inability of traditional knowledge to effectively manage soils. As Tenywa *et al*. (2013) argued that traditional knowledge has failed to promote soil management for improving resilience and recovery, and failed to support communities in building confidence towards making management decisions to achieve their objectives. This was due to institutional failures such as lack of incentives and information; lack of a framework for integrating traditional knowledge with scientific knowledge which requires review by policy makers (Tenywa *et al*., 2013). Studies have examined how knowledge is disseminated between extension and farmers in order to understand how extension facilitates uptake of knowledge intensive GAPs to aid the effectiveness of sustainable agriculture policies (Ingram, 2008).

Table 3.4 Qualitative table for GAPs.

GAP	Soil improvement	Water conservation	Both
Cover crop	+	+	+
Mulching	+	+	+
No-till	+	+	+
Crop rotation	+	+	+
Rooftop water harvesting	0	+	-
Composting	+	+	+
Appropriate fertilizer application	+	0	-

Note: +=Positive impact; 0= No impact.

3.6 Chapter summary

This chapter explored sustainability issues in agriculture taking the northern Nigerian context. It also presented innovations around sustainable agriculture in drylands while considering policies that will support the attainment of the multiple goals of food security, environmental stewardship and poverty reduction. Policies and investment that focus on natural resource management without taking into account household strategies for food security are bound to fail (Vosti and Reardon, 1997b). Resilience to climatic shocks will require a shift from current food systems management to a new system with institutional and technological changes in the pattern of consumption, production, and distribution of food (Jerneck and Olsson, 2008). Despite the success of sustainable agriculture, the challenge is how to 'scale up' the gains (Pretty, 1997). GAPs are suggested in a sustainable framework for promoting farmer productivity while protecting environmental goods and services. This sets the stage for improving the environmental responsibility of farming in the case study areas. The first stage will be to develop a research methodology which is the focus of the next chapter.

CHAPTER FOUR

Research Design and Methodology

This chapter presents the research methodology, design and underpinning philosophy.

4.1 Background and statement of study objectives

This chapter presents the methodology adopted in this study, describing all the stages from study areas selection, philosophical considerations, research design, sample selection, data collection and analytical methods and other ethical concerns to meet the research objectives. Principal component analysis being the main quantitative analytical technique is also discussed. Qualitative focus group discussions (FGDs), in-depth interviews and extension agents and stakeholder engagement were used to verify the quantitative findings.

As stated in the first chapter of this thesis, the overall aim of the research was to explore how dryland agriculture could be made sustainable while enhancing the capacity of drylands households to be resilient to environmental challenges and to improve their food security using Good Agricultural Practices (GAPs). The specific objectives of the research engagement are to: (i) assess the vulnerability conditions of the dryland farmers to environmental challenges and identify opportunities for resilience; (ii) examine the extent of use of good agricultural practices by North-Western Nigerian dryland farmers and how they are conditioned by extension, culture and local economy; (iii) examine and evaluate farmer knowledge and understanding of global and local environmental challenges and their attitudes to these challenges; (iv) select, set up and test prioritised GAPs based on review of scientific evidence and evaluate with farmers the outcomes of the tested GAPs; (v) appraise the barriers for non-adoption and process of adoption so that lessons learnt can be transferred into more effective extension.

4.1.1 The study locations and reasons for the choice

Zango is an arid farming community in the Zango Local Government Area of Katsina state, bordering the Republic of Niger. It has an area of 601 km² which is situated at latitude 13^{o} 03' 19.0" North and longitude 8^{o} 29' 17.2" East. Total annual rainfall is approximately 591 mm, which supports the production of cereal and legume crops. Cereals farmed include sorghum (*Sorghum bicolar*) and pearl millet (*Pennisetum glaucum*), while legume crops include: cowpea (*Vigna unguiculata*), soybean (*Glycine* max) and groundnuts (*Arachis hypogaea*). Irrigation agriculture, being a ready source of food and important for managing short-term stresses in drylands, is not practiced in Zango.

Kofa, on the other hand, lies between the Semi-arid and Sudan Savannah agro-ecological zones of Nigeria in Bebeji Local Government Area of Kano state in North-West Nigeria. Bebeji occupies an area of 717 Km^2 and a population of 188, 859 people using the 2006 census figures i.e about 263 people per Km^{-2}, a high population density of people which could exert pressure on land (Lambrecht *et al.,* 2016). It lies on latitude 9^o 41’14.6” North and longitude 7^o 41’12.4” East and enjoys annual rainfall average of 835 mm. Baseline study of Kofa community shows that farmers were involved mainly in cereal {maize (*Zea mays*), sorghum (*Sorghum bicolar*), and millet (*Pennisetum glaucum*)}, legume {cowpea (*Vigna unguiculata*), soybean (*Glycine* max), and groundnuts (*Arachis hypogaea*)} crops and some vegetables {onions (*Allium cepa*), tomato (*Solanum lycopersicum*), and garlic (*Allium sativum*)} production. Inhabitants of the both Zango and Kofa are mostly farmers and all of them practice Islamic religion.

The study locations were purposively selected with the aim of studying the agricultural practices of areas affected by rainfall shortages (drought) and land degradation to study the perceptions of, and responses of the dryland inhabitants to drought and other environmental challenges, so that improvements in practices can be made where necessary. Communities without such experiences may not have knowledge of environmental and climate change thereby making it difficult to explore these issues in those areas. As seen in the figures (2.2 and 2.3) in chapter 2, there is indication that Zango is experiencing changes in climatic variables. Zango is ideal for exploring vulnerability to drought as previous studies have found the area to be adversely affected by the increasing climate events (Abiodun *et al.,* 2011). Kofa however, was chosen to compare practices and results in terms of farming systems, and farm characteristics which are beneficial in comparative studies (Fisher, 2012).

The two study locations were selected based on similarity in some socio-economic and cultural attributes, low level of women participation in farming due to cultural and religious reasons, predominantly mixed cropping and livestock integration practiced in the two communities. The ecological zones of the two communities are illustrated (Map 4.1).

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Map 4.1 Map of Nigeria showing the two study communities and the ecological zones.
Source: Okpara *et al.* (2013)

4.2 Philosophy and ontology

This research uses human subjects as participants since the research is socially based. Protagoras has contended that "*man is the measure of all things*", a statement which has been at the centre of debate in the history of Western Philosophy (Johnson *et al.,* 2007; pg. 113). Here 'man' refers to both gender. This argument has continued to shape how knowledge is viewed, "*what we look for, what we expect to find, and how we believe we are to go about finding and justifying 'knowledge'*" which is premised under the primary philosophy of pragmatism (Johnson *et al.*, 2007; pg. 113). Moreover, in studying a phenomenon or subject, researchers are expected to adopt a paradigm and to ensure proficiency through integration at the level of data analysis in qualitative and quantitative mixed methods (Cameron, 2011).

The main aim of this thesis is to explore how agricultural resilience can be promoted in the drylands of north-western Nigeria from both farmers' perspective and scientific evidence which favours a pragmatic approach, as opposed to taking a single positivist or interpretivist paradigm. A single approach may be inadequate in solving the research objectives. Pragmatism is concerned with getting practical about solving problems. This is informed by experience as opposed to theory; mostly viewed as ‘anti-philosophy’ (Johnson and Onwuegbuzie, 2004). It supports pluralism and eclecticism (i.e conflicting and even different perspectives and theories can be used in gaining understanding and knowledge of the world and people). This is with the hope that ‘real world’ researchers pass through their researches conveniently without considerations given to the philosophical justifications of social research (Johnson and Onwuegbuzie, 2004). Under pragmatism, different data collection methods are employed in the research to address a particular problem (Creswell, 2013).

4.2.1 Theoretical Frameworks

Theory has been defined by Bryman (2012) as:

“*a set of well-developed categories…that are systematically related through statements of relationship to form theoretical framework that explains some relevant social…or other phenomenon.”*

Theory in social research is very important as it provides the rationale for the conduct of a piece of research. It also gives a framework for understanding the social phenomenon and for interpreting research findings (Bryman, 2012). Theoretical considerations can arise after collection and analysis of some or all data and not necessarily before research is commissioned, which refers to an inductive approach or ‘inductivism’ (Bryman, 2012). The opposite of ‘inductivism’ is ‘deductivism’, where theory or hypothesis is developed and data collected to prove or disprove the theory or hypothesis (Robson, 2011). Deductivism is a natural science approach that assumes research has to be advanced through a well-defined theoretical approach (Robson, 2011). The inductive approach was used in this research as theories were employed after data collection and analysis.

Inductivism favours the development of theory from data collected (Bryman, 2012). Inductive approaches are mostly about designs, not only type of data collected, and are referred to as flexible designs. Data collected is non-numerical, but mostly appear as words, although sometimes some quantitative data are collected alongside (Robson, 2011). Under this paradigm, reflexivity of the researcher is important (Robson, 2011). That is, the researcher’s biases need to be acknowledged in interpreting the findings of the research.

Three theories and conceptual frameworks were found useful in this research:

i. Theory of Planned Behaviour (TPB): This theory was borrowed from Ajzen (1991; 2011; 2015) and used to explore attitude and intention of the participants towards adoption of GAPs for climate change adaptation after related themes emerged from the in-depth interviews. Consequently, meeting objective 3 of this study.
ii. Innovation Diffusion Theory: This theory is widely used in adoption of innovation studies and adapted from Rogers (1995; 2003). It was used for meeting objective 5 of this study.
iii. Vulnerability-Resilience: This conceptual framework was adapted from Reed and Stringer (2016). It was used in meeting objective 1 of this study.

a. Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) (Ajzen, 1988, 1991) has received widespread application as a conceptual framework for the study of human action (Ajzen, 2001). According to the theory:

> *People act in accordance with their intentions and perceptions of control over the behaviour, while intentions in turn are influenced by attitudes toward the behaviour, subjective norms, and perceptions of behavioural control* (Ajzen, 2001:43).

Furthermore, according to Ajzen (2002: 665), human behaviour is influenced by three factors:

> *Beliefs about the likely consequences of other attributes of the behaviour (behavioral beliefs), beliefs about the normative expectations of other people (normative beliefs), and beliefs about the presence of factors that may further or hinder performance of the behaviour (control beliefs).*

The TPB has been applied successfully to studies of behaviour in different fields such as food consumption decisions (Fishbein and Ajzen, 2010; Ajzen, 2015) and behaviour related to health (for a review see Conner and Sparks, 1996). However, only a few studies have applied the Theory of Planned Behaviour to climate change adaptation (Lin, 2013; Masud *et al.,* 2016) with almost no application in the context of Nigerian drylands based on available knowledge. The role of intention and behavioural control in influencing behaviour has been previously studied (see Ajzen, 1991 for a review). Ajzen (2002) suggested that behavioural beliefs lead to an unfavourable or favourable attitude concerning the behaviour. Normative beliefs, however, lead to subjective norm or perceived social pressure. Control beliefs on the other hand result in 'perceived behavioural control, the perceived ease or difficulty of performing the behaviour' (Ajzen, 2002: 665). These three factors when combined, give rise to 'behavioural intention'.

i. **Behavioural beliefs (attitude towards behaviour):** A body of knowledge exist on the nexus between attitudes and behaviour (Ajzen, 2001). Attitude is said to enable adaptation to the environment (Prislin and Ouellette, 1996; Eagly and Chaiken, 1998). For example, in a study of recycling behaviour, Schultz and Oskamp (1996) asserted that as concern for the environment increases so does recycling behaviour. In psychology, the attitude construct is captured in traits such as 'good-bad, harmful-beneficial, pleasant-unpleasant, and likable-dislikable'. This implies, however, that only one attitude is held towards any given issue or object (Ajzen, 2001: 28).

Conversely, some studies argue that this conception of attitude informing behaviour appears rudimentary; because people can possess two attitudes concurrently where one attitude may be implicit and the other explicit. To recover the explicit evaluative response in favour of the implicit, capacity and motivation are required (Ajzen, 2001). As such changes in attitude alone does not necessarily make the new attitude prevail over the old one (Wilson *et al.,* 2000). Hence, different interpretations of the same object depending on context are considered proof for dual 'attitudes toward the same object, or attitudes toward different psychological objects' (Ajzen, 2001: 29).

ii. **Normative beliefs (subjective norms):** Ajzen (2001) opined that individual belief links an object with a trait, and an individual's general evaluative response concerning an object is dependent on the 'subjective values of the object's attributes in interaction with the strength of the association'. Despite the possibility of people forming different beliefs concerning an object, the assumption is that only views that are readily available in memory influence attitude at any given instant (Ajzen, 2001). Indeed, beliefs adjudged to be important are easy to recall as demonstrated by spontaneous responses (van Harreveld *et al.,* 2000). Subjective norms consider a 'person's beliefs about whether significant others think he should engage in the behaviour' (Conner and Armitage, 1998). These significant others are people whose opinions concerning a person's behaviour in this context are useful to that individual. Subjective norms also denote the social pressures on individuals to accomplish a behaviour or not.

iii. **Control beliefs (perceived behavioural control):** This concept is linked to the theory of 'self-efficacy' originally proposed by Bandura (1977; 1982). Later Bandura (1982: 122) suggested that:

"Efficacy in dealing with one's environment is not a fixed act or simply a matter of knowing what to do. Rather, it involves a generative capability in which component cognitive, social, behavioural skills must be organized into integrated courses of action to serve innumerable purposes".

Potentials of personal ability determine initiation of coping behaviour, amount of effort to be used, and time taken to be sustained when faced by obstacles and 'aversive experiences' (Bandura, 1977: 191). As when faced with challenges, people with serious doubts about their capabilities make less effort or give up completely while those with a 'strong sense of efficacy' make more effort to overcome the constraints.

Moreover, it is expected that with real control over a behaviour, intention to perform should be carried out when the opportunity arises. However, actual control is limited by difficulties associated with execution of certain behavioural intentions; hence, 'perceived behavioural control' is considered (Ajzen, 2002). Perceived behavioural control like subjective norm and attitude are measurable by directly probing about 'capability to perform a behaviour or indirectly based on beliefs about the ability to deal with specific inhibiting or facilitating factors' (Ajzen, 2002: 668). All the actual determinants of control over behaviours are difficult or almost impossible to quantify in most applications of the TPB, hence, perceived behavioural control is used as a proxy based on the premise that perceptions of control echo actual control practically well (Ajzen, 2015).

The critics of the TPB have argued that the theory is limited in its ability to determine intention. This is because it does not determine a certain association between intentions and behaviour to understand how attitude can impact goal attainment (Conner and Armitage, 1998). Similarly, the TPB is argued to be concerned about the salience of individuals' beliefs which may not align with the researcher's beliefs (Conner and Armitage, 1998). Other critics such as Bonnes *et al.* (2003) assert that the TPB is limited by its inability to address the '*social dilemma*'; that is, collective outcomes are affected by 'individual's behavioural achievement' (Serenari *et al.,* 2012). Despite perceptions of the TPB as being over simplistic, it has received wider application as a model for predicting human behaviour very well in different fields (Ajzen, 1991; 2011), it is therefore used in this study to predict farmers' behaviour towards adaptation to short-term weather and long-term climate change conditions through the adoption of GAPs.

b. Innovation Diffusion Theory

Theories have been formulated that explains the predictors of innovation adoption including: Cognitive Dissonance Theory, Innovation Diffusion Theory, Task-Technology Fit Model, Expectation-Disconfirmation Theory, Theory of Reasoned Action, Theory of Planned Behaviour, Social Cognitive Theory, Technology Acceptance Model, and the Unified Theory of Acceptance and Use of Technology (for a review, see Samaradiwakara and Gunawardena, 2014). According to Samaradiwakara and Gunawardena (2014), some of these theories have shortcomings such as risk of confusing attitudes with norms, as they can be interchangeable, and may not be applicable in certain conditions. Hence, this study employs the Innovation Diffusion Theory (Rogers, 1995; 2003) which was adjudged appropriate in this context to interpret some findings.

Rogers in his classic study (1995; 2003) identified five features that determine adoption rates of an innovation: compatibility, complexity, trialability, observability and the relative advantage of the innovation. In addition, incentives either in cash or in kind and benefits to be derived speed up the rate of innovation uptake (Rogers, 1995; Shiferaw *et al.,* 2009). Rogers (1995) further opined that the time of the adoption of an innovation by an individual is determined by his/her innovativeness [allied to their observation of others] and thus identified five sequential adopter classifications: 'innovators, early adopters, early majority, late majority and laggards'. While these adopter typologies are important, it is beyond the scope of this thesis to further explore them in detail. Meijer *et al.* (2015:42) suggested that the process of adoption is also influenced by 'so-called receiver variables, such as personality characteristics, social characteristics and the perceived need for the innovation'. Similarly, Rogers (2003) argued that the diffusion of innovation theory affirms that innovation spreads over time based on the social context of the innovation, the extent of promotion by change agents, its features and the channel the innovation is communicated (Rogers, 2003).

Grounded on the mixed method research paradigm, this study is underpinned by both interpretivist and positivist epistemologies (pragmatic) as one method- e.g. qualitative method is more appropriate in achieving a research objective than the other (Saunders *et al.*, 2012). Many important considerations underline epistemological thoughts and one of such is the belief that knowledge is 'induction driven' i.e a 'bottom-up' process by which forms arise from observing the world while those that view knowledge acquisition through deduction, take a 'top-down' approach (Ormston *et al.*, 2014). Interpretivism in this context is favoured by the argument that the subject matter of research viz-a-viz people and their institutions fundamentally differ from those of the natural sciences (Bryman, 2012). Social reality has a meaning for human beings and by implication human actions. Hence, human action has meaning i.e "*they act on the basis of the meanings that they attribute to their actions and the actions of others*" (Bryman, 2012). Social scientists have the responsibility of knowing the "*common sense thinking*" of the people and to interpret their actions and their social environment from the point of view of these people (participants) (Bryman, 2012). *Interpretivism* gives importance to the understanding of the social world through interpretation (Ormston *et al.,* 2014).

A conflict arises from the duality of perspectives on the framing of climate change adaptation which is either shaped by lived experiences of dryland inhabitants or external facilitation which determines the ontological considerations in this study. That is whether a social world is regarded as external to social actors (objectivism) or as something that people are in the process of fashioning (Bryman, 2012). Hence taking either an objectivist or constructivist position. A subjective view on the adaptation in drylands will be that the process evolves through a dynamic interaction between drylands inhabitants and their environment. Although this is perceived to be reductionist, an objective view will argue that the adaptation is fuelled by an external support targeted at vulnerable farmers who will be overwhelmed by the vagaries of new climatic events.

- **Reflexivity/ Researcher's positionality**

Awareness of the place of the researcher in the process of writing the qualitative component of the research is important. Here reflexivity reminds the researcher of the possibilities of bias in terms of the personal experiences and values the researcher brings to the study (Creswell, 2013). Two issues about reflexivity come to bear in a qualitative research: firstly, the experience of the researcher in relation to the phenomenon being studied, secondly, the discussions around how these experiences influence how the researcher interprets a phenomenon (Creswell, 2013 p. 216). I was conscious of my background and understanding of the drylands conditions and reflected that throughout the process of the research, so that my personal biases will not mirror in the outcome of the research. Hence, detaching myself from the research.

4.3 Research Design and Strategies (Mixed methods)

Social science research encompasses scientific fields ranging from Human Geography, Social Policy, Sociology, Politics, and Criminology and it leverages on the social science methods to formulate research questions and to interpret and draw conclusions from findings (Bryman, 2012). Choice of research design and methods influences the direction of a piece of research. Mixed methods techniques were employed using one method to inform the next in a participatory way (sequential). Farmers' experiences of environmental challenges of dryland agriculture are combined with carefully selected GAPs to co-develop specific farmer action plans through the research team in association with extension agents for training farmers and to re-visit farmers to assess adoption or not along with reasons for such farmer decisions. It is anticipated that this top-down science-based evidence allied to the bottom-up experience of it will lead to improved adoption and extension and help inform policy developments in the future. This evidence is used to engage extension workers and farmers in their understanding and use of such practices.

In terms of sample selection, sampling is very important in research because it underpins the quality of inferences that would be made by the researcher from research findings (Onwuegbuzie and Collins, 2007). It is always difficult to come up with a sample size for a mixed methods research due to the need to select different samples for the quantitative and qualitative components. Despite the body of knowledge on mixed methods research, very little has been written on sampling (Onwuegbuzie and Collins, 2007). Before a sampling method is chosen, researchers must state the objective of the study. However, in a research where the aim is not to generalise to a population but rather to get insights into an issue, people or events, the researcher can purposely select people, groups and settings for the purpose of understanding the subject in question (Onwuegbuzie and Collins, 2007; Robson, 2011; Creswell, 2013). Hence, in studying the drylands adaptation strategies, case study communities (Zango and Kofa) were purposively sampled as appropriate for the study.

Today, the dynamism, complexity and interdisciplinary nature of research calls for one method to be complemented with another as researchers are also called to ground themselves in mixed methods as utilised by others for easy communication and to promote a collaborative research (Johnson and Onwuegbuzie, 2004). This research design that combines a qualitative and quantitative method in a single research work also known as the third research methodological paradigm has gained widespread acceptance in the behavioural and social sciences literature (Johnson *et al.*, 2007; Combs and Onwuegbuzie, 2010; Cameron, 2011). This is evidenced by increased publications in this area, increased number of research using this method and the new Journal of Mixed Methods Research founded by Sage Publishers in 2007 (Bergman, 2008a).

Mixed method involves the application of more than one method or source of data in the study of social phenomena also known as triangulation (Bryman, 2012) with pragmatism taken as the philosophical position (Robson, 2011). Exploratory or descriptive issues can be better investigated using quantitative methods while in-depth probing and group dynamics about happenings and behavioural influences are better approached qualitatively. That is in terms of sensitivity to how participants interpret their social world (Bryman, 2012). In terms of sampling size for a mixed method research, large sample size is used for the initial survey (quantitative) while a smaller size is employed for an in-depth qualitative explanatory study (Cresswell *et al.*, 2008). A quantitative survey method was initially used to collect baseline data on the existing practices of households, means of livelihood, demographics, farm enterprises, perceptions and knowledge of environmental challenges and responses. Stakeholder interviews (semi-structured) were carried out to obtain research and extension opinions on current research and extension on drylands farming around the study communities. In-depth interview (structured) and focus group discussions were also employed to further investigate issues emanating from the survey and to seek opinions on best approaches to deploying interventions on enhancing resilience that led to a participatory co-learning activity. A final survey was conducted to collect data on adoption and reasons for non-adoption of interventions and based on the Theory of Planned Behaviour.

Some researchers argued that Qualitative (QL) research is grounded on the theory that is either created or is non-existent, while Quantitative (QN) research, however, theoretically supports the presence of a single reality (Bergman, 2008b). The growth witnessed in strategic and practically oriented research that conform to the needs of users has emphasised on the dissemination of outcomes. Hence, the need for researchers to speak the technical language of research and the language that makes research handy to a wider audience (Brannen, 2008). Therefore, words must be considered as important as numbers which can only be achieved using mixed methods research. Though reporting them together in a written format has proved difficult and findings from quantitative studies could probe further insights using qualitative methods (Brannen, 2008).

A research design provides a framework for the collection and analysis of data (Bryman, 2012). In social science research, three criteria should be considered before the selection of a research design; reliability (repeatability), replication (is it replicable with all procedure well spelt out?) and validity (integrity of conclusions) (Bryman, 2012). This study design is presented in (Figure 4.1). Research methods, on the other hand, are tools for data collection (Saunders *et al.*, 2012) such as questionnaires, interviews, observations (Denscombe, 2014) and data analysis (Robson, 2011).

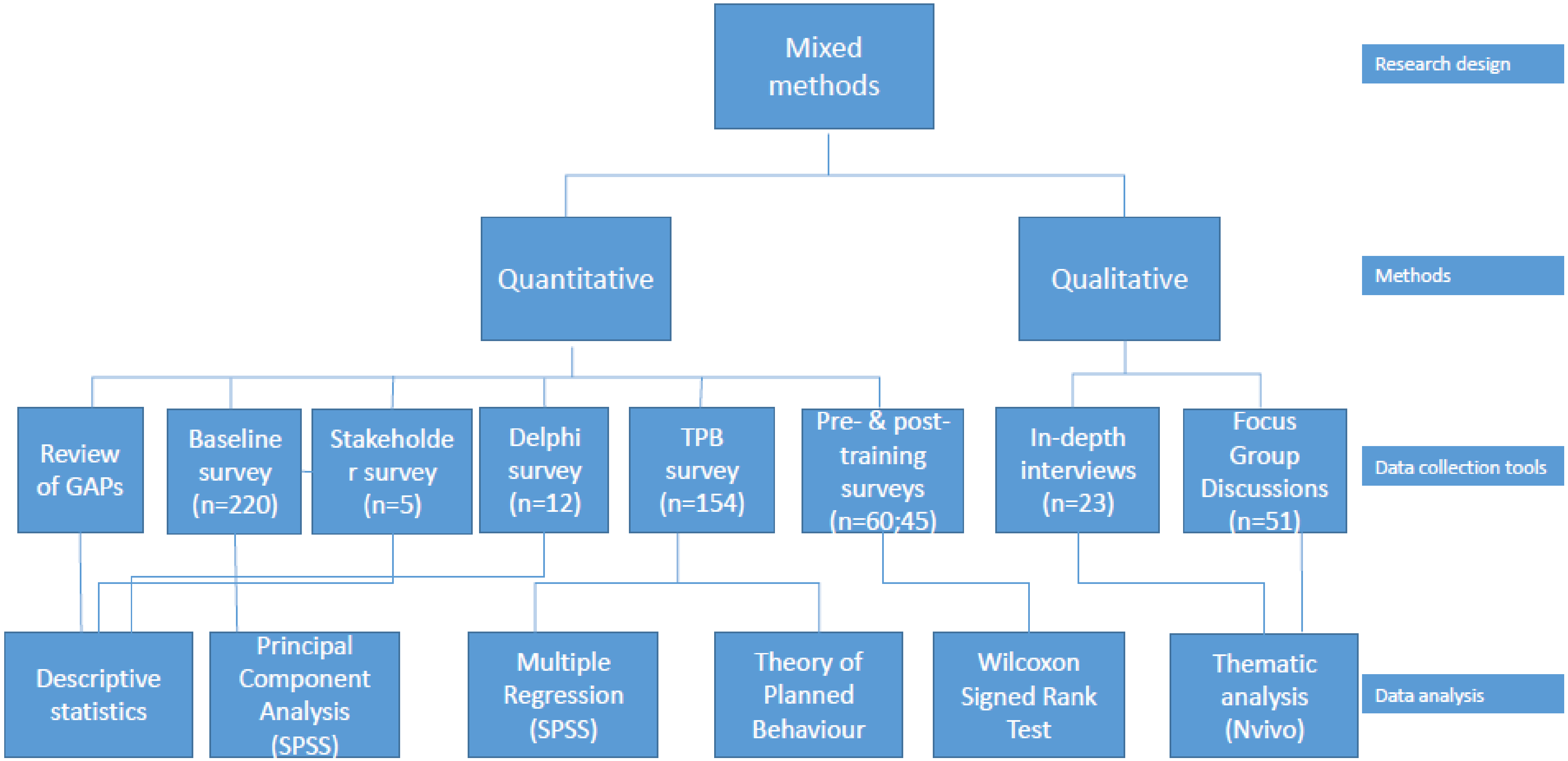


Figure 4.1 Design framework of the research methodology.

4.3.1 Case study design

A case study includes an individual, set of individuals, communities, institutions, roles and 'cross-national studies' as a unit of measure (Robson, 2011). It is defined by Yin (2014: 2) as:

"an empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-World context, especially when the boundaries between phenomenon and context may not be clearly evident."

This methodology enables the researcher to investigate a social process in a more detailed fashion and also helps in having a good grasp of complex social interactions such as the dynamic nature of social behaviour (Widmer *et al.*, 2008; Denscombe, 2014). A case study is believed to be one of the most applied analytical concepts in social science methodology. For something to qualify as a case, it must possess some qualities that support studying it independent of its context (Denscombe, 2014). Although, its conceptual foundations have not been well established; the methodology is much weaker compared to other forms of social research. However, there appears to be hope with the use of this methodology as its proponents argue that case study research provides in-depth knowledge and appreciation of a single unit or of a smaller number of units which helps in avoiding misleading conclusions (Widmer *et al.*, 2008). Hence, the choice of Zango and Kofa as case studies.

4.3.2 Participatory Action Research (PAR) and Direct Observation

Observation encompasses watching what people do, listening to them and sometimes asking questions to clarify (Gilham, 2000). Observation was used at the second field visit to verify findings from the baseline survey around current practices of farmers and level of household food security. A participatory approach to research, however, evolved due to the failures of 'top-down' approach to research in the 1970s and 80s which focused on modifying the approach to research and development in agriculture (Thompson and Scoones, 2009). It is a qualitative method of data collection in the field of Human Geography, where a considerable number of researchers have utilised in their research and whose aim is to appreciate the world based on people's understanding and lived experiences (Crang and Cook, 1995; Thompson and Scoones, 2009). PAR tries to discourage the notion that an 'insider' or research 'expert' and the ‘outsider’ participant are the norms because participants are the ‘experts’ of their circumstances (Chambers, 1983; Ritchie and Ormston, 2014). Rather it promotes the involvement of practitioners (in this case poor rural farmers) in research processes and development aimed at improving their farming practices (Thompson and Scoones, 2009). Participation focuses on securing local resources and action, is an empowering process and aims to heuristically enable the people to act for themselves. This approach favours a transition from data collection to data sharing and enablement (Chambers, 1994). Hence, its use in this study as a means of empowering farmers in the long-term.

An inquiry into aims of a social research suggests that research should add to the stock of knowledge about the social community (Bryman, 2012). However, others argue that research should have a practical aim and that it should add value to the World we live in i.e social science research should be focused on issues and topics beneficial to practice which supports evaluation and action research (Robson, 2011; Bryman, 2012). Action research is aimed at changing aspects of something (e.g. practices) or influencing it, which involves partnership between researcher and participants (Robson, 2011). The participatory nature makes it a distinct form of social research which, incorporates views of beneficiaries, as equal stakeholders and the ‘outside expert’, playing the role of a facilitator (Denscombe, 2014).

According to Shiferaw *et al.* (2009), policies to manage land degradation initially included ‘forced adoption of soil erosion control, planting of trees on hill-sides, and protection of water/river catchments’ all of which are top-down approaches. Later this method was criticised for limiting ‘farmers’ ability to innovate, adopt and adapt improved land and water management practices’ (Shiferaw *et al.*, 2009: 260). This led to the emergence of ‘farmer-led’ methods of soil and water management practices that were tagged the ‘populist’ approach as promoted by Chambers *et al.* (1989) in their famous edited book ‘Farmer First: Farmer Innovation and Agricultural Research’ which challenged the linear top-down approach to innovation diffusion.

When tackling new and more extreme environmental change issues, local knowledge is often insufficient for building capacity for adaptation (Frank *et al.*, 2011) but on the other hand, farmers' perceptions of scientific knowledge could affect the application of science-based decision-making (Cash *et al.,* 2002). Hence the need to integrate local and scientific knowledge in a participatory way. However, the adoption of any science-based improved practice in the absence of any incentive will be dependent on the cost of implementing the practice set against the perceived viability and benefits at the individual farm level (Knowler and Bradshaw, 2007). The use of incentives by external agents to offset costs or create benefits has been found to be important for supporting adoption of agroecological practices (Brockington *et al.,* 2016). As an example, training and investment in infrastructure can promote benefits for adoption in form of rural job creation and food security of households (De Haen, 1997). Furthermore, as suggested by FAO (2004), innovations will not only promote climate change mitigation and adaptation in drylands but will enhance triple wins which include: food security and poverty reduction. However, a much-debated question is whether training alone will be sufficient for innovation uptake considering its perception by smallholders as a 'top-down' approach. The introduction of such innovations needs to be participatory in order to build capacity in communities as participatory approaches provide benefits to socio-ecological system's management.

An intermediate between top-down and participatory development may be to adopt participatory co-learning in order to promote participant and extension agent ownership of the process. This could start from existing farmer innovation and the identification of gaps in farmer strategies that could be filled by new 'scientifically proven' practices to complement what is already being done. This would result in development project planning that integrates scientific and farmer experiential knowledge and may also address the suspicion of science knowledge by local farmers. Despite the benefits of PAR, it is difficult to achieve within the timeframe of a PhD. Hence, the body of work done for this thesis, has set the foundation for further interaction and co-learning with the two communities in this study.

Co-learning on good agricultural practices adoption for resilience enhancement was carried out in a participatory way and results of the process is reported in chapter seven.

4.3.3 Survey

This is a method of data collection used in the mixed design which deals with a representative sample of a known population and mostly carried out for descriptive purposes (Robson, 2011). Findings from this method are perceived by some researchers as an outcome of a detached set of respondents who respond to questions in a manner to reflect a friendly disposition to the interviewer which may not be the true reflection of the zeitgeist of that moment (Robson, 2011). Also, surveys are said to reflect the social reality of the researcher as opposed to the subject (Chambers, 1983). However, when thoughtful appraisals are made prior to the survey design and when combined with other methods, surveys are sufficient (Chambers, 1983). In this method of data collection, it is difficult to know the characteristics of non-respondents (Robson, 2011). A survey is associated with quantitative research to give a picture of current conditions rather than giving a long-term perspective of things; and ranges from postal, face to face, telephone and internet surveys (Denscombe, 2014). This could be either highly structured questionnaire survey (closed ended) or semi-structured survey (with some open-ended questions) (Crang and Cook, 1995).

A livelihood survey tool was adopted in this study, but with slight modifications (appendix 5). It was important to minimise non-response error and measurement bias as a poorly designed questionnaire could potentially lead to 'low response rates' (Fisher, 2012), while questions that are poorly constructed could result in inaccurate and misleading responses (Dillman, 1991). Hence, a thoughtful consideration was given to wording of questions, design, and layout of the survey tool. Also, ambiguous questions such as questions that could have more than one meaning were avoided and questions contextualised to ensure clarity of responses.

Thirty-six questions were asked on the livelihood section to gather data on farmer's and household demographics; gender, literacy level; household food security, assets, labour availability, land size, water source, crop input requirements, and extension support. Twenty-nine additional questions based on findings from the literature review were asked to cover three other sections that comprise farmer enterprises, perceptions on climate and environmental challenges and autonomous adaptation strategies with the last two questions on farmer willingness to continue research and additional comments on the research. The questions were mostly fixed-alternative questions using ‘yes/no’ responses while others were open-ended and scale questions. Although fixed alternative questions are argued to be superior to open-ended questions due to ease of responding, fewer interviewer skills are required, and less time to answer (Zikmund and Babin, 2007).

The suitability of the questions for social science analysis was determined by a social science researcher at the Royal Agricultural University and poorly framed questions were corrected. A pilot interview was carried out separately with two MSc students in the University with feedback given and corrections made before the research was conducted. Another tool for stakeholder engagement (appendix 8) was developed and piloted by an experienced African researcher.

Non-probability sampling techniques (snowball sampling-for study communities and purposive sampling for respondents) were employed during the baseline study in order to explore new ideas and theories (Denscombe, 2014). The aspect of snowball sampling was in establishing contacts with the Centre for Dryland Agriculture, Kano-Nigeria that provided links with the field officers in the two communities. This method of sampling is accepted and will continue to be widespread in ‘real world research’ (Robson, 2011). In social research, such sampling is used to purposively choose a set of people that will give the best responses to the problem being researched. However, it was ensured that different age groups, social groups, and gender were represented. Although it is argued that this sampling method is not likely to produce representative samples of the population, it is important for conducting development work on new interventions (Bryman, 2012) as it is suitable for a pilot study.

The unit of measurement in this research is individual farming household. Household, as referred by Ellis (1993) consists of a group of individuals who belong to the same residential setting and carry out different economic activities for production and consumption at the same time. In Kofa community, one hundred (100) households were surveyed from the 200 households in the extension block (sample frame) based on the willingness of respondents to volunteer time (45-60 minutes) to be surveyed. Kofa community had experienced few rainfalls before the field visit in July 2015 which encouraged farmers to start their cropping season and crops sown had established and were at the stage of first weeding. In the second community (Zango), 120 households were surveyed from the 1000 households in the extension block as farmers were found idle and willing to be interviewed due to the late start of the farming season. This was because there was no rainfall up until the end of June 2015. Hence, the disparity in the number of respondents in the two communities. Cases of non-response and refusal to participate in research have been a growing concern in the literature as some researchers have reported a declining trend in response rates to social surveys in many countries (Bryman, 2012).

The baseline data were collected in the Kofa and Zango communities using Hausa language between June and July 2015. Extension agents, retired extension staff, and some literate locals were recruited to help with collecting the data after intensive training on interviewing skills and how to correctly interpret the questions. The surveys were carried out in different villages for farmers willing to be administered questionnaires in all the villages that make up the communities to ensure an even spread. When no more respondents were willing to be administered questionnaires in Zango community, the research team moved to the second community Kofa. The survey was executed in a timely fashion and without incidences with the cooperation of the locals and help from their community heads and stakeholders.

Surveys were mostly carried out with heads of households or spouses, elderly son/daughter in the absence of the household head. To be qualified as a respondent, one must have been involved in farming for at least 5 years under their parents or on their own. It took between 45 to 60 minutes to administer a questionnaire. Each interviewer was expected to interview 3 household heads maximum per day to ensure the quality of responses. The questionnaires were checked for missing sections by the researcher personally every day after data collection and where data were missing, the person responsible was requested to revisit the household and complete the missing sections. Similar stringent measures were used for the TPB survey, in-depth interviews, and FGDs.

The survey provided the baseline information to allow me to do the Principal Component Analysis and data for the TPB survey was used for the Multiple Regression.

- ***Principal Component Analysis***

Principal component analysis (PCA) also referred to as factor analysis was used to determine the extent of similarities among variations and to reduce the data to a manageable size while retaining much of the characteristics of the original variables (Joliffe, 2002). Suitability of data for PCA was determined namely: sample size at least 150 cases if there are high loadings (above 0.8) on variables; the strength of inter-correlations of items on the correlation matrix for coefficients (greater than 0.3) (Tabachnick and Fidell, 2014); and factor analysis may not be appropriate if only a few correlations above 0.3 are found. Other statistical criteria generated by SPSS are Bartlett's test of sphericity (Bartlett, 1954) which must be significant at ($p \leq .05$) and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (Kaiser, 1970, 1974) whose index ranges from 0 to 1, and taking 0.6 as the minimum value for factor analysis to be appropriate (Tabachnick and Fidell, 2014). A few techniques also help with the decision on the number of factors to retain: Kaiser's criterion also known as eigenvalue rule is used where only factors with an eigenvalue of 1 and above are retained for further investigation. This is because the eigenvalue represents the amount of total variance explained by the factor. Other factors include Catell's scree test (Catell, 1966) which plots each eigenvalue of the components using SPSS and inspecting the line to see where the shape changes direction to become horizontal (elbow) (Pallant, 2013), the test recommends retaining all factors above the elbow. Parallel analysis is another technique in the social sciences which compares the size of the eigenvalues with those randomly generated from a dataset of the same size. Only eigenvalues that are greater than the corresponding values from the randomly generated data set are kept (Pallant, 2013).

- ***Multiple regression***

This investigates the relationships in the Theory of Planned Behaviour (TPB) for the determinants of intention to adapt to climate change. Reliability of the responses was tested using Cronbach's coefficient alpha values for internal consistency in the responses. A total of 154 of the respondents were surveyed based on the Theory of Planned Behaviour (TPB) questionnaires. Results of the PCA and multiple regression are presented in Chapter five.

4.3.4 Delphi technique

A Delphi technique was employed to obtain consensus on expert opinion about the GAPs selected for uptake by the farmers, the potential of GAPs as sustainability strategies, adaptation and appropriateness for water, soil fertility and pest and diseases management in the North-Western Nigerian drylands. The suitable means of engagement and utility of GAPs to farmers in these areas were further explored. A Delphi technique was found appropriate due to its ability to provide evidence from experts in the field of the benefits of using GAPs by the research participants, and due to its cost effectiveness in eliciting diverse opinions.

The Delphi technique commenced with gaining knowledge (scientific evidence behind use) of the GAPs from a review of the literature, as first rounds can be replaced by this process. Subsequently, the second round was sent to 38 participants selected based on their contributions (research and experience) in the field of study from the literature reviewed, practitioners in the field and through snowballing (referred by other participants). Eleven participants responded to the second round which accounted for 29 % response rate. Suggestions were taken, and the second round was modified and sent to 25 participants (i.e 10 returning respondents who answered ‘yes’ or ‘maybe’ they should be contacted except for 1 returning participant who said ‘No’ he should not be contacted. The additional 15 participants for the third round were from the names suggested by the 11 participants that responded to the second round. Out of the 25 participants contacted, only 12 responded which makes up 48% response rate with most of the items achieving over 75% agreement and all the respondents agreed to have the report of the study sent to them. The Delphi approach is further explored, and results are reported in chapter 6.

4.3.5 In-depth interviews

This refers to a method for describing and interpreting the social world which is an important qualitative data collection method that offers the researcher the opportunity to probe further the factors supporting a respondent’s responses; their past experiences, values, circumstances, beliefs, opinions, and feelings (Yeo *et al.*, 2014). Qualitative strategies are important in eliciting the farmer’s perspectives without being influenced by the researcher’s point of view (Creswell, 2013). Accordingly, a qualitative interviewer must be an active listener, have the stamina to be able to extract the opinions and experiences of respondents "in their own words". If well conducted, an interview is very important as it gives a researcher the privilege to access the respondent's "*social world*"; their experiences and meanings ascribed to them, which supports the researcher during data analysis. A poorly conducted interview becomes problematic in getting a good analysis done (Yeo *et al.,* 2014).

4.3.6 Focus Group Discussions

Focus Group Discussions (FGDs) are interview methods that involves more than one participant. However, researchers have not agreed on the specific number of participants as others argue for at least four interviewees (Bryman, 2012), between 6 and 8 (Silverman, 2014), 6-9 people (Denscombe, 2014). Placing emphasis on the number of participants allows participants to explore a topic in detail (McDaniel and Gates, 1999). Here, specific themes are explored in-depth to get a group view of an event or interaction and the researcher or facilitator is not expected to be too intrusive while moderating (Bryman, 2012). Despite its time consuming and expensive to organise nature (Denscombe, 2014), it is used in seeking divergent views and not consensus (Crang and Cook, 1995; Finch *et al.,* 2014).

In FGDs, a tightly defined topic is explored to get a shared creation of meaning which is regarded as '*more naturalistic*' and also helps researchers to develop an understanding of why people feel the way they feel (Bryman, 2012; Crang and Cook, 1995). Also by hearing from others, perceptions of participants are likely to change (Finch *et al.,* 2014). Three FGDs were conducted per community for three separate groups (women, older and young farmers) to get different perspectives on the topics explored. This method was used for vulnerability analysis and to identify the best approach to field engagement based on participants' point of view. Results are reported in chapter eight.

4.4 Access

In social research, issues of negotiating access to participants is a major consideration. In the study communities, access to participants was through the Centre for Dryland Agriculture, Bayero University Kano-Nigeria who introduced the researcher to the extension officers in the two study communities. In getting to the communities, gatekeepers were contacted such as the community heads to introduce the purpose of the research and to explain the expectations from the participants to gain access.

4.5 Ethical considerations

In dealing with human subjects in social research, issues of ethics are important and need to be given due attention to ensure the participants are not unnecessarily exposed to any form of risks by their participation. The researcher submitted the tools needed for engaging with households in the two communities to his supervisory team who checked with the University ethics committee and approval was given to continue with the field engagement. This was due to lack of any sensitive issues to be discussed in the engagement process which could potentially predispose the respondents to any risk. However, consent forms (appendix 4b) were read out together with statements of confidentiality of the research and protection of participants to freely get the consent of the participants. The participants were also informed that they are free to opt out of the research at any time they feel not comfortable to continue. Although, they were informed that their opinions were valuable to the researcher in understanding their experiences of environmental challenges and how resilience capacities can be enhanced in the drylands of north-western Nigeria.

4.6 Selection of tools for data analysis

Statistical Packages for the Social Sciences (IBM-SPSS©) version 22 was used for entering, coding, and cleaning data for quantitative analysis. Graphs, charts, and tables were used to display data analysed. Principal component analysis (PCA) was employed to better appreciate the data and relationships between and among key variables.

Computer-Aided Qualitative Data Analysis Software such as (Nvivo©) have seen much patronage recently in easing the process of qualitative data analysis. Nvivo was employed in coding and analysing qualitative data collected from the FGDs and in-depth interviews to identify relevant themes and categories. Pictorials and the use of narrations were also employed.

4.6.1 Rationale for choice of tools

To build confidence about the rigor of a study, a researcher must seek out and explore the differences and similarities between multiple perspectives on the research issue (Crang and Cook, 1995). Currently, the three paradigms of qualitative, quantitative and mixed methods research are all thriving as each approach has its strengths and weaknesses; times and places of application (Johnson *et al.,* 2007). Johnson *et al.* (2007) suggested that mixing methods is not only limited to the concept of triangulation, nonetheless researchers tend to eliminate possible weaknesses in the research design by the combination of methods that have separate weaknesses. And the need to strategically mix quantitative and qualitative approaches, concepts and methods to produce "*complementary strengths and non-overlapping weaknesses*" cannot be over-emphasized (Johnson *et al.,* 2007). Considering the importance of mixed method research, it is crucial to justify its choice and to clearly state the philosophical foundations and pragmatic positions taken (Cameron, 2011) as applied in this thesis.

4.7 Research limitations

The possibility of bias in selection is acknowledged, as households were not chosen randomly but purposively and based on the researcher's knowledge of the area and farming systems practiced in northern Nigerian drylands. Hence, the findings of the study may not be generalizable, but will offer insights on the applicability of GAPs for sustainability of dryland agriculture.

4.8 Chapter summary

This chapter highlighted the general research strategy and design, which was mixed methods. It explained the rationale behind the choice of methods for data collection to achieve the research objectives. The main approach was quantitative design using baseline survey, TPB survey, and stakeholder engagement. The complementary design was qualitative which comprised FGDs, in-depth interviews to triangulate the methods. Practical issues and theoretical support were considered to ensure good research practice. The results of the quantitative and qualitative data collected are presented in the preceding chapters.

CHAPTER FIVE

Results of baseline and Theory of Planned Behaviour

This chapter resulted in a paper sent for publication as follows:

- Jellason, N.P, Baines. R.N. and Conway, J.S. ‘Climate risk perceptions and attitudes to adaptation of smallholders in north-western Nigerian drylands’ Environmental Science & Policy (Newly submitted)

The objectives of this chapter are to:

- explore climate change perception of farming households and adaptation responses in two communities in north-western Nigerian drylands using Principal Component Analysis (PCA).
- determine how perception influences attitude towards adaptation behaviour for future climatic challenges using Theory of Planned Behaviour (TPB).

5 Introduction

Climate change impacts are projected to be experienced globally, however, developing countries dependent on the environment for their livelihood are expected to be worst hit by the resultant variability in climate (Adger *et al.*, 2003; IFAD, 2011; AGRA, 2014) and this will further affect food production and security (Dang *et al.,* 2014a). In the same vein, ecosystem services loss due to degradation is projected to worsen in the first half of the current century (MEA, 2005) which will impede the attainment of the Sustainable Development Goals. Climate change impact on food production in drylands is of interest because they occupy 41 percent of the terrestrial land surface and have experienced high human population growth (FAO, 2011). These areas are home to over 2 billion people globally who generally live under subsistence conditions (Thomas, 2008a).

Moreover, an anticipated rise in temperature of 1-3^{o} C is expected in drylands by 2050 because of doubling of CO_2 to 700 p.p.m which will further expose smallholders to uncertainties, especially sub-Saharan African (SSA) dwellers (Kurukulasuriya and Mendelsohn, 2008). Variability and change in rainfall are understood to determine the nature of investment for productivity enhancement and natural resources conservation in drylands of SSA (Mortimore, 2000; Stringer *et al.*, 2009). In these areas, it is argued that temperature rises and droughts conditions are increasing or rather likely to increase, most especially in the Nigerian Sahel due to climate change. If not urgently addressed, this will impact negatively on the environment and result in a loss of 2 to 11 percent of Nigeria's GDP by 2020 (equivalent to US$100 billion) (Federal Ministry of Environment Climate Change Department, 2011).

Given the evidence that dryland smallholders have survived for long periods, then it is reasonable to assume that they have developed adaptive strategies to the weather patterns they have frequently encountered (Stringer *et al.*, 2009). However, these strategies will likely be insufficient amidst new climatic changes in the future (IPCC, 2007). Despite the external stress experienced, action must be influenced by a perceived need, motivation and ability to act (Frank *et al.*, 2011). Hence, this chapter aims to explore climate change perception of farming households and adaptation responses in two communities in north-western Nigerian drylands using Principal Component Analysis (PCA). Furthermore, the chapter will determine how perception influences attitude towards adaptation behaviour for future climatic challenges.

5.1 Climate change and risks perceptions

Climate change is considered a risk to agricultural productivity, as production risk arises from the unpredictability of weather and uncertainties around crop and livestock performance (Hardaker *et al.*, 2004). Risk perception is significant in decision-making (Maye *et al.*, 2012) because all decisions have future consequences which are unpredictable, hence, the need to prepare for possible consequences and tackle them holistically (Hardaker *et al.,* 2015). The debate in the climate change adaptation literature points to several factors that are responsible for adaptation decisions on climate change. Examples of such factors include socio-economic, technical and institutional factors such as: ownership of assets (Scoones, 2009); access to credit and extension information (Deressa *et al.,* 2009; Hisali *et al.*, 2011; Fosu-Mensah *et al.,* 2012); investments in rain-fed agriculture and efficient rainfall utilization (Wani *et al*., 2009); and land tenure security (Hisali *et al.,* 2011).

However, most past studies did not consider the perception of risk as a key determinant of adaptation to environmental shocks and stresses (Bandura, 1977; Stehr and von Storch, 1995; Weber, 1997). This was also supported by studies building on earlier works on socio-cognitive determinants of adaptive behaviour that question resource consideration alone (Patt and Gwata, 2002; Grothmann and Patt, 2005; Deressa *et al.,* 2011; Jones and Boyd, 2011). Grothmann and Patt (2005) further asserted that neglecting the role of cognition in the adaptive decisions of those affected by climate change will be counterproductive to attaining current and future adaptive capacity. This is because integrating human perceptions to the adaptation process will address the shortfalls of the socio-economic, technical and institutional determinants of adaptation that are most often promoted. Therefore, before adaptation can take place, climate change must be perceived to be happening, hence, the role of perception as a precursor to adaptation cannot be overemphasized (Maddison, 2007; Bryan *et al.,* 2009; Deressa *et al.,* 2011; Tambo and Abdoulaye, 2013).

In Africa, directing climate communication research towards breaking the socio-cognitive and behavioural barriers to adaptation is important (Shahadu, 2012). This is because the continent has some of the weakest links around resource and institutional ‘adaptive capacity’ (Boko *et al.*, 2007). Poor perception of individual capacity to minimise and adapt to human impacts on climate change allied to poor knowledge of the links between awareness of the causes of climate change and human behaviour constitute significant limitations to climate change education and communication (Pruneau, Khattabi, and Demers, 2010). Therefore, to explore the role of perception in influencing adaptation behaviour, the Theory of Planned Behaviour was employed in this study.

5.2 Materials and Methods

This study was carried out in North-Western Nigeria. It is part of a broader pragmatic mixed method study which set out to record baseline climate change perceptions and adaptive strategies of a total of 220 households in two communities and, a follow-up survey built upon the Theory of Planned Behaviour (TPB) with 154 of the households available at the follow-up stage to explore attitude towards adaptation behaviour to climate change.

5.2.1 Study Area

The two communities were purposely selected for comparative reasons and are differentiated by their long histories of dryness (Map 4.1). See section 4.1.1 for details.

5.2.2 Sampling

Non-probability sampling technique was employed based on the household head’s willingness to participate in the study. Sample households were not necessarily representative of the population at large, but indicative of the two farming communities under slightly different dry conditions. An aspect of snowball sampling was employed to initiate contacts with the Centre for Dryland Agriculture, Kano who provided links to the field officers working in the study communities.

To ensure no non-response bias, characteristics of respondents in the two communities were assessed to be typical of communities interviewed in the second wave of the Living Standard Measurement Study (LSMS) (National Bureau of Statistics *et al.*, 2014). In the LSMS, younger populations for males between age 20 and 30 and females less than 30 years old have higher literacy rate compared to the older population, and average household size around 6.1 in rural areas, this was reflected in the two communities (Table 5.3).

5.3 Development of Questionnaires

A livelihood survey tool (appendix 5) was employed with thirty-six questions asked on the livelihood section to gather data on household demographics; food security indicators, assets, labour availability, land size, water source, crop input requirements and extension support. A further twenty-nine questions were asked to cover three sections that comprise farmer enterprises, perceptions, causes and effects of climate and environmental challenges, source and accessibility of climate information; the language of communicating climate information, level of satisfaction with information received; and autonomous adaptation strategies. The last two questions were on farmer willingness to continue research and any additional comments.

Questionnaires on the TPB were developed based on the emerging themes from the initial qualitative interviews conducted. The TPB questionnaires explored subjective norms, perceived behavioural control, attitudes and behavioural intention for climate change adaptation. The TPB measured direct determinants of subjective norms, attitudes, and intentions. Perceived behavioural control (PBC) on the other hand was measured based on the ease or difficulty of carrying out the adaptation practices as influenced by internal and external controls. These were mapped as follows: Internal control, 'If I wanted to, it is easy to integrate adaptation in my farming' (1 = strongly disagree, 4 = strongly agree); and, External control: 'Not having enough resources makes it difficult to adapt to climate change' (1 = strongly disagree, 4 = strongly agree). Scoring responses were based on a four-point Likert scale, thus avoiding the neutral or average response (Lozano *et al.*, 2008) (Table 5.1).

Table 5.1 Variables measured for attitude, subjective norm, perceived behavioural control and intention to adapt to climate change for the Theory of Planned Behaviour.

Items	Scale*
Direct attitude	
For me, climate change adaptation is	(very irrelevant – very important)
Climate change adaptation on my farm is	(very difficult – very practical)
Adaptation to climate change for me is	(very inconvenient – very convenient)
Subjective norm	
I feel under pressure from extension agents to integrate adaptation to climate change in my farming	(strongly disagree – strongly agree)
People whom I respect (e.g. community head) will disapprove if I do not integrate adaptation in my farming	(strongly disagree – strongly agree)
It is expected of me to integrate adaptation to climate change in my farming since others are doing it	(strongly disagree – strongly agree)
Perceived behavioural control	
If I wanted to, it is easy to integrate adaptation in my farming	(strongly disagree – strongly agree)
Not having enough resources makes it difficult to adapt to climate change	(strongly disagree – strongly agree)
Whether I integrate adaptation into my farming is entirely up to me	(strongly disagree – strongly agree)
Behavioural intention	
I intend to integrate adaptation in my farming	(very unlikely - very likely)

*Variables measured against a four-point Likert scale and bipolar adjectives

5.4 Data analysis

Data collected were entered into IBM SPSS© quantitative statistical software version 22, coded, cleaned and analysed using descriptive statistics to profile the baseline conditions of farmers in the two communities before applying Principal component analysis (PCA) (Morgan *et al.*, 2007; Pallant, 2013). PCA was used and all statistical criteria for the PCA were satisfied before the test was carried out. Perception variables were selected based on a review of literature for variables linked to climate change perceptions (Table 5.2).

Table 5.2 Climate change perception variables selected for PCA based on literature review.

Perception variable	Reference
Poor fertility of most soils	Swe *et al.* (2015).
Decrease in arable yield	Ndamani and Watanabe (2015).
Increased drought	Smit *et al.* (1996), Okonya *et al.* (2013).
Change in rainfall pattern	Smit and Skinner (2002), Okonya *et al.* (2013).
Poor humidity/dryness	Okonya *et al.* (2013).
Increase in temperature/hot	Smit and Skinner (2002), Okonya *et al.* (2013).
High sunshine intensity	Mehar *et al.* (2016).
Increased rate of erosion	Author
Flooding	Okonya *et al.* (2013).
Pest and diseases	Bryant *et al.* (2000), Brklacich *et al.* (2000), Swe *et al.* (2015).

The TPB was used as a guide to predict attitude, subjective norm and perceived behavioural control that are likely to determine the intention to adapt to climate change among participants. Multiple regression was employed to forecast adaptation intention along with Cronbach's alpha coefficient for measuring internal consistency to measure the reliability of the TPB questions; significance levels set at 0.05.

5.5 Results

Two sets of results are presented here, the first focuses on communities' baseline conditions while the second focuses on the application of the Theory of Planned Behaviour (TPB).

Survey I result – livelihoods and perceptions of climate change

5.5.1 Community baseline conditions

Respondents from the two communities comprised different age groups, gender, marital status, family size and educational qualifications. These are summarised (Table 5.3).

Table 5.3 Demographic characteristics of Zango and Kofa communities.

Demographic characteristics	Zango (%) n=120	Kofa (%) n=100
Age		
21-40	32.5	55.0
41-60	64.2	37.0
61 & above	3.3	8.0
Gender		
Male	83.3	87.0
Female	16.7	13.0
Marital status		
Single	1.7	6.0
Married	95.0	93.0
Widowed	3.3	1.0
No. of children		
0	0.8	9.0
1-5	31.1	48.0
6-10	44.5	26.0
11-15	21.0	10.0
16 & above	2.5	7.0
Highest education		
No education	32.5	33.0
Primary	19.2	35.0
Secondary	30.0	13.0
Tertiary	18.3	19.0

The types of houses and domestic water source in the communities are important for adaptation. Roof types of houses in Zango comprise corrugated iron zinc (57.5 %), and others (38.3 %) which consist of mud roof and asbestos, while a high percentage (93.0 %) of households in Kofa have corrugated iron zinc roof, which supports water harvesting for domestic uses and potentially vegetable garden production. Household characteristics considered in this study include, among others: capital assets, radio and mobile phones ownership; irrigation equipment; livestock assets; land ownership and title; household labour; and source of employment. Despite the presence of irrigation facilities in the outskirts of the Zango community, the type of agriculture mainly practiced is rain-fed which is 100 % in Zango and 93 % in Kofa.

In agrarian economies dependent on natural resources, roles, responsibilities, and assets are differentiated by gender. In the two study communities, women involved in farming mostly own plots in backyards while the men manage plots in distant places. Land is controlled by the household heads who were mostly men or widows. In the case of female-headed households, both nearby and distant lands are controlled by these women. Although gender can determine the coping strategies adopted under climate change scenarios (Mehar *et al.*, 2016), female-headed households were too few in this study to accurately determine this phenomenon.

5.5.2 Household experiences of environmental change

Many respondents in Zango reported that environmental change caused discomfort at work with less effect on their health. However, it greatly reduced their farm productivity as most of the respondents believed environmental change increases drought, reduced soil fertility, and prolonged heat stress leading to reduced crop yield; however, this had not affected herd sizes as yet. In Kofa, most respondents strongly agreed that environmental challenges reduced farm productivity, but disagreed that it caused property destruction and increased erosion (Figure 5.1). As can be visualized in the two communities using Mean of responses, climate change associated effects are felt at different magnitudes on the various activities and the sectors highlighted.

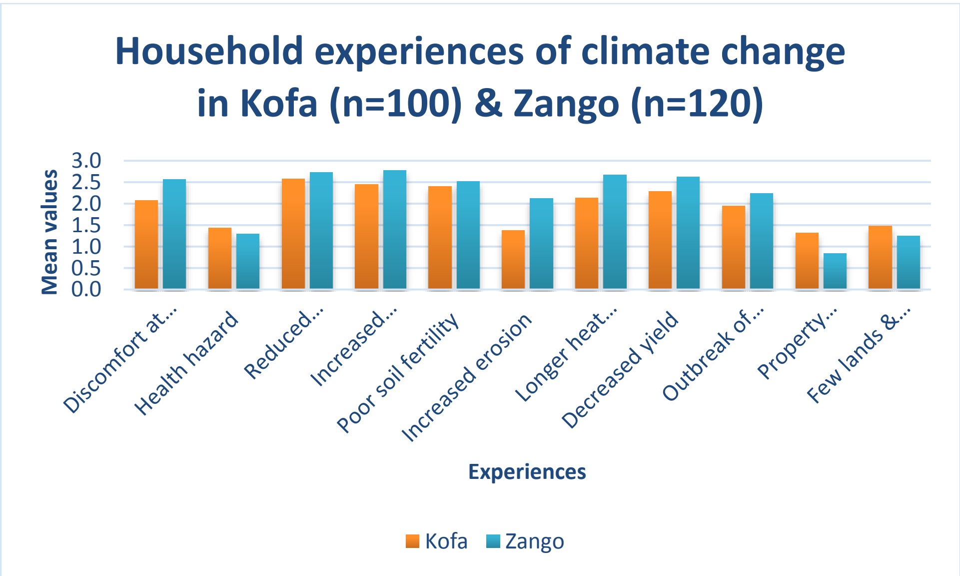


Figure 5.1 Household experiences of climate change (Mean values) in Zango (n=120) and Kofa (n=100) communities.

5.5.3 Source of Climate Information

The radio was ranked as the most important source of climate information in the two study communities. Eighty-eight percent of respondents in Kofa and all respondents in Zango reported radio as the major source of climate information. Research institutes and internet were ranked as the least important source of climate information in the two communities. Television was recorded as an important source of climate information in Kofa but not in Zango.

A Chi-square test for independence (with Yates Continuity Correction) showed significant association between gender and access to extension, χ^2 (1, n=220) = 5.75, *p*=.017, *phi* = -.18. This implies that the proportion of males who have access to extension is significantly higher than the proportion of females who have access to extension in the two communities. This is argued to be due to cultural barriers that limit female participation in northern Nigerian agriculture and a limited number of female extension agents that will interface with the women (De Schutter, 2013). Access to climate information through modern means of communication such as television, internet and from research institutes did not indicate any gender sensitivity but was low overall (Figure 5.2). This suggests that communications need to be improved upon to enable households to have access to up-to-date information, early warnings, and new drylands technology to help in their decision-making for adaptation.

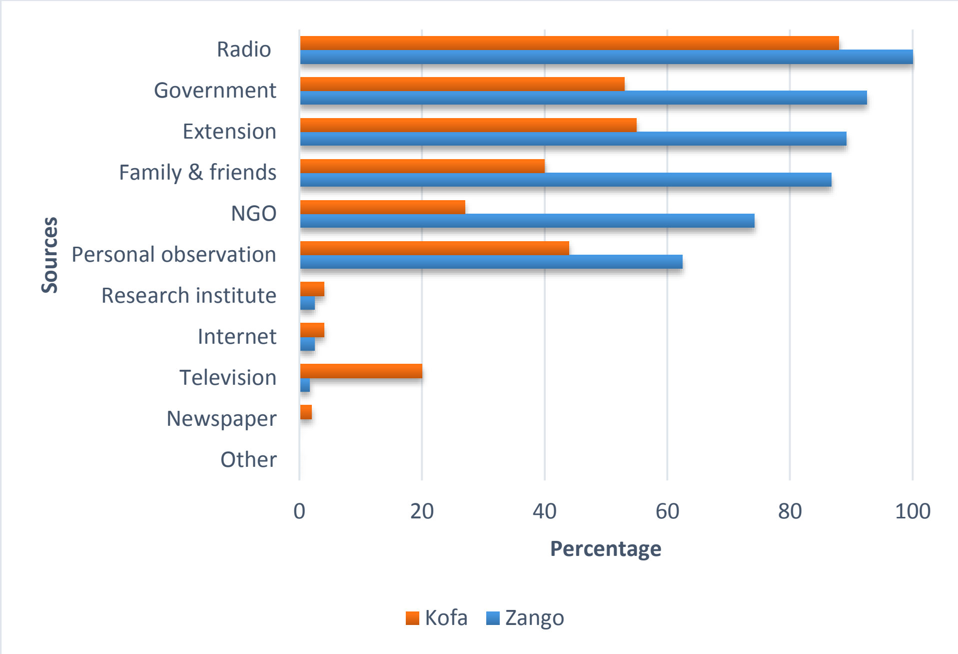


Figure 5.2 Source of Climate information in Zango (n=120) and Kofa (n=100).

5.5.5 Perceptions of environment and climate change awareness

Principal component analysis (PCA) was used to explore perception and environmental change awareness. The PCA was used to extract factors and oblique factor rotation was done using the Oblimin method (Pallant, 2013). Ten items on the environmental change perception scales were selected based on evidence in the literature on impacts of environmental and climate change (Table 5.2) and subjected to PCA. The factors combined accounted for 64.51% of the total variance of the 10 environmental change awareness variables provided by the 220 households. Data suitability for factor analysis was verified before conducting the PCA. The correlation matrix showed that many coefficients were 0.3 and above (Table 5.4). The Kaiser-Meyer-Olkin value was 0.61, which is slightly above the 0.6 recommended value while Bartlett's test of sphericity attained statistical significance ($p<0.05$); random figures from parallel analysis showed figures for only the first two cases were less than the eigenvalues for the extracted factors which makes PCA appropriate (Pallant, 2013).

PCA showed four components with eigenvalues more than 1, which explains 24.1%, 15.9%, 12.8% and 11.7% of the variance respectively. The scree plot when inspected showed a significant break after the fourth component and using Catell's (1966) criteria scree test, two components were retained for further analysis. The results of Pattern Matrix further supported this decision which showed two components with 3 items each having 0.3 or more loading on each component. The two components explained 40% of the total variance, component 1 contributing 24.1% and component 2 contributing 15.9% and the various variables loaded on each component. To assist in the interpretation of the two components, Oblimin rotation was carried out (Pallant, 2013). The rotated solution revealed the presence of simple structure (Thurstone, 1947), with both components showing some strong loadings. There was a weak positive correlation between the two factors (r=0.11). The result suggests that component 1 was made up of variables that portray temperature and heat-related signs of the environment changing, while component 2 showed variables related to change in rainfall (Figure 5.3); this informed the choice of sustainable practices after training in these practices as part of the research intervention (Chapter 7). These included practices such as reduced tillage, cover cropping (living mulch), and crop rotations.

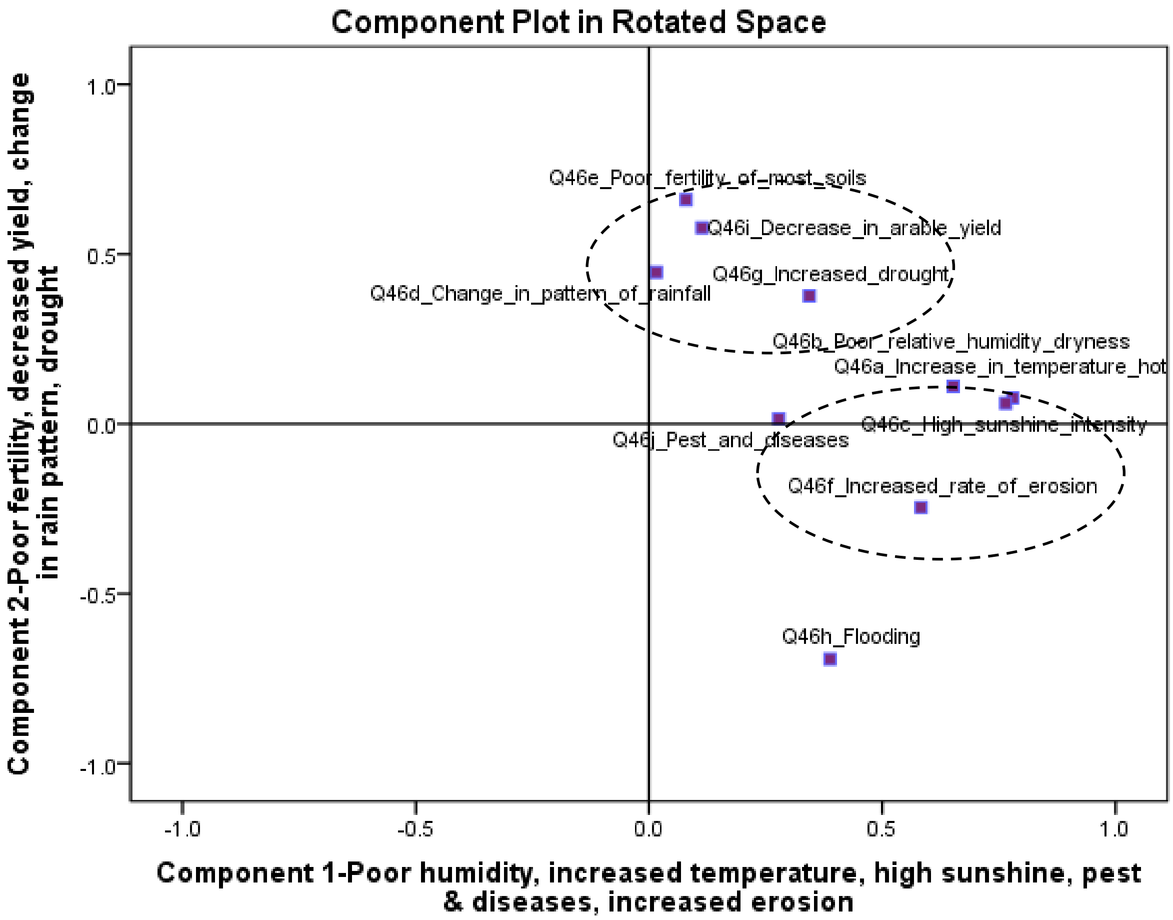


Figure 5.3 Component Plot in Rotated Space for both communities.

A radar graph was plotted for the perception factors against their percentage of variance contributed and is presented on (Figure 5.4). Correlations between the environmental change awareness indices and loadings of the environmental change parameters are presented (Table 5.4). While Pattern and structure Matrix loadings on the two components together with their communalities are presented (Table 5.5) as the top four high values were more climate-related.

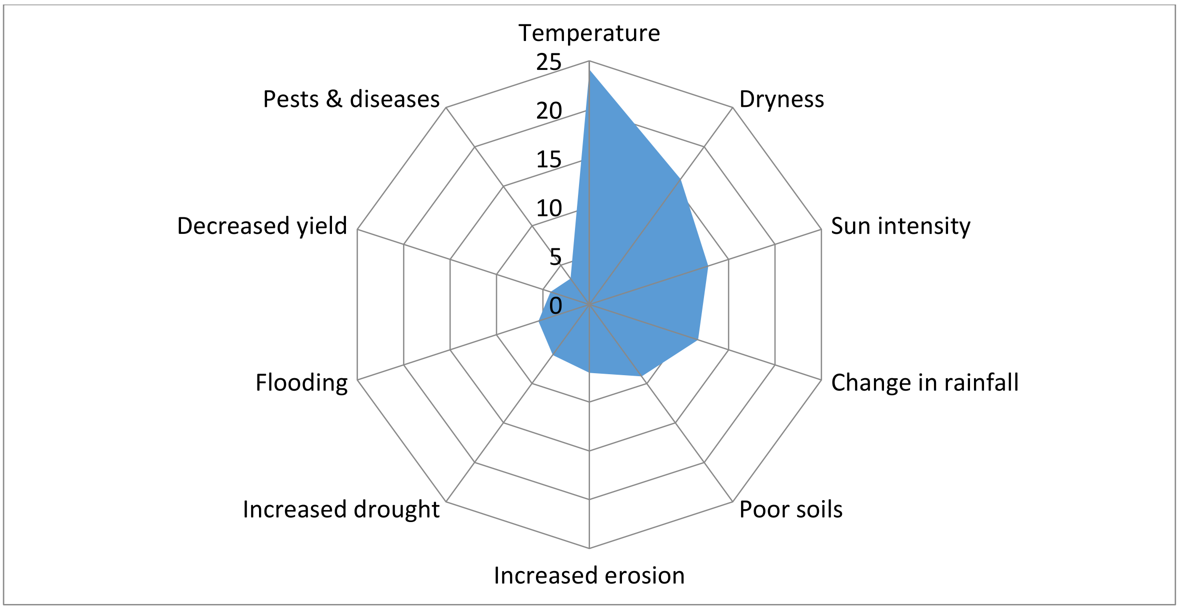


Figure 5.4 Perception variables and percentage strength of variance from a PCA.

The factor scores of the households from the two communities (n=220) were analysed together but plotted separately on scatter plots (Figure 5.5 & 5.6). These factor scores represent the scores of each household on the perception variables which is used to visualise and assess the perceptions on environmental change awareness on the perception variables in the two communities and their loadings on the two components.

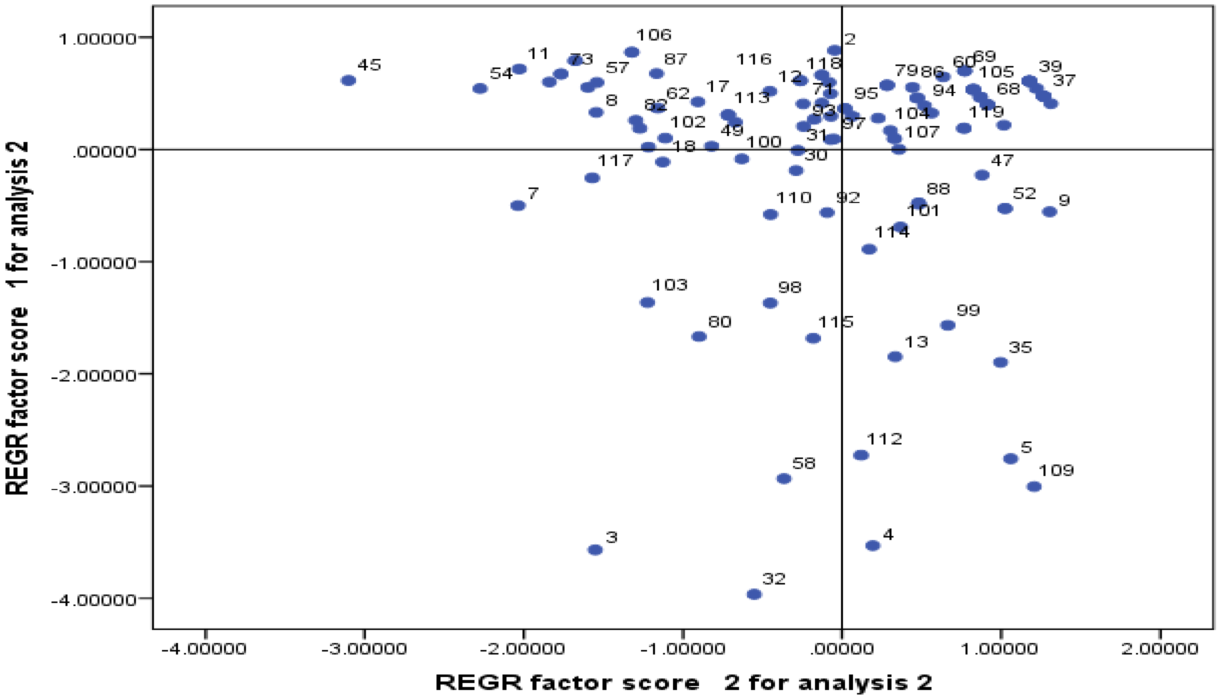


Figure 5.5 Scatter plot of households in Zango from the 2 PCA factors.

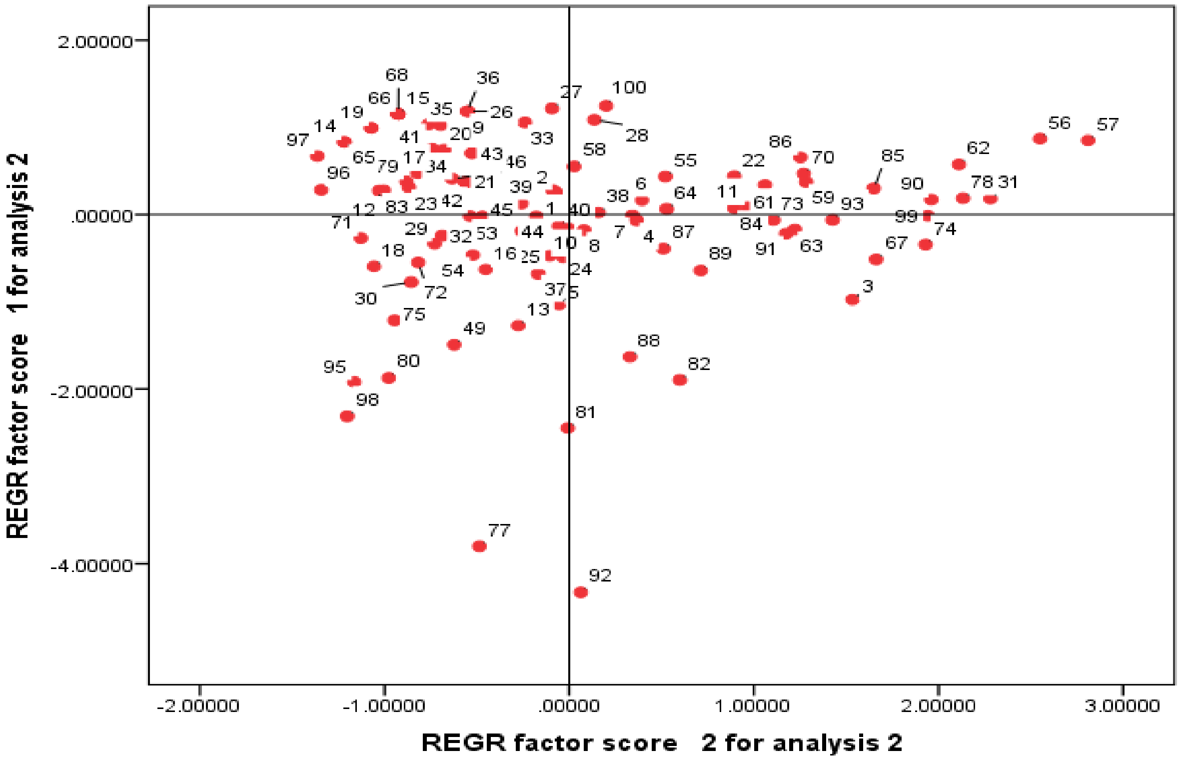


Figure 5.6 Scatter plot of households in Kofa from the 2 PCA factors.

5.5.6 Gender differences

A Mann-Whitney U Test was conducted to identify the presence of any significant difference between the perception of males and females for the two communities separately on the ten perception variables. Only three variables in Zango showed significant difference; increased rate of erosion ($U=235.0$, $p<0.05$), Flooding ($U=753$, $p<0.05$) and Pests and diseases ($U=334.5$, $p<0.05$). In Kofa one variable; High sunshine intensity ($U=385.0$, $p<0.05$) showed a significant difference. This implies that there was no significant difference in perception of climate change in both communities based on gender except for the variables highlighted above. That is, in both Zango and Kofa communities, men perceived climate change more than women in all the variables. This may not be surprising due to the disproportionate percentage of male respondents which was higher than female respondents in both communities. Hence, this unequal representation could bias the difference in perception towards male respondents.

5.5.7 Age and education differences

A Kruskal-Wallis test was conducted to explore the presence of a significant difference in perceptions of environmental change awareness based on age and the highest level of education attainment of respondents in the two communities, no significant difference was recorded on any of the perception variables.

Table 5.4 Correlations matrix between perception variables.

	Increased temperature /hot	**Poor humidity/ dryness**	**High sunshine**	**Change in rainfall pattern**	**Poor fertility of soils**	**Increased erosion**	**Increased drought**	**Flooding**	**Decreased arable yield**	**Pests & diseases**
Increased temperature/ Hot	**1.000**	**.483**	**.630**	.150	.057	.212	.123	.085	.150	.125
Poor humidity/ Dryness		**1.000**	**.399**	.034	-.002	.162	.274	-.004	.127	.047
High sunshine			**1.000**	.108	.068	.202	.198	.084	.091	.157
Change in rainfall pattern				**1.000**	.128	-.078	.048	-.155	.094	-.009
Poor fertility of soils					**1.000**	.197	**.322**	-.216	**.301**	.087
Increased erosion						**1.000**	.249	**.363**	-.043	.143
Increased drought							**1.000**	-.059	.112	-.078
Flooding								**1.000**	-.126	.096
Decreased arable yield									**1.000**	.213
Pests & diseases										**1.000**

Table 5.5 Pattern and Structure Matrix for PCA with Oblimin Rotation of Two-Factor Solution of Perception elements.

Item	**Pattern coefficients**		**Structure coefficients**		**Communalities**
	Component 1	**Component 2**	**Component 1**	**Component 2**	
Increased temperature	**.779**	.076	**.788**	.165	.626
High sunshine intensity	**.765**	.061	**.772**	.149	.599
Poor humidity/dryness	**.652**	.111	**.665**	.185	.454
Increased erosion	**.583**	-.246	**.555**	-.179	.367
Pest & diseases	.278	.015	.280	.046	.078
Flooding	.388	**-.693**	.309	**-.648**	.569
Poor fertility of soils	.080	**.659**	.115	**.669**	.453
Decreased yields	.113	**.577**	.179	**.590**	.361
Change in rainfall pattern	.016	**.447**	.067	**.449**	.202
Increased drought	.344	.377	.387	**.416**	.290

Note: major loadings for each element are in bold.

5.5.8 Climate change adaptation practices

Addressing environmental and climate challenges of farming in the drylands of north-western Nigeria will require an understanding of existing practices of farming households. Despite not been exhaustive, current adaptation practices uptake in the two study communities show some good practices ongoing. However, good practices such as mulching for water and fertility management, rehabilitating problems of soil sealing and compaction (which results in low water infiltration in drylands, Kidane, 2010) was poorly adopted as indicated in the baseline survey (Figure 5.7). Similarly, a few households adopted irrigation in Kofa, compared to no uptake in Zango. In contrast, agroforestry was highly adopted in both communities. Further, improved varieties of crops were highly used by most respondents in Kofa and all respondents in Zango community due to access to improved seeds from ICRISAT being an external intervention. There was a higher rate of uptake of intercropping and crop rotation in Zango compared to Kofa community (Figure 5.7). This negates the argument by Akande and Ogundele (2009) who suggested that despite the viability of these practices in soil and water management, only a few farmers in Nigeria are engaged in the uptake of these practices.

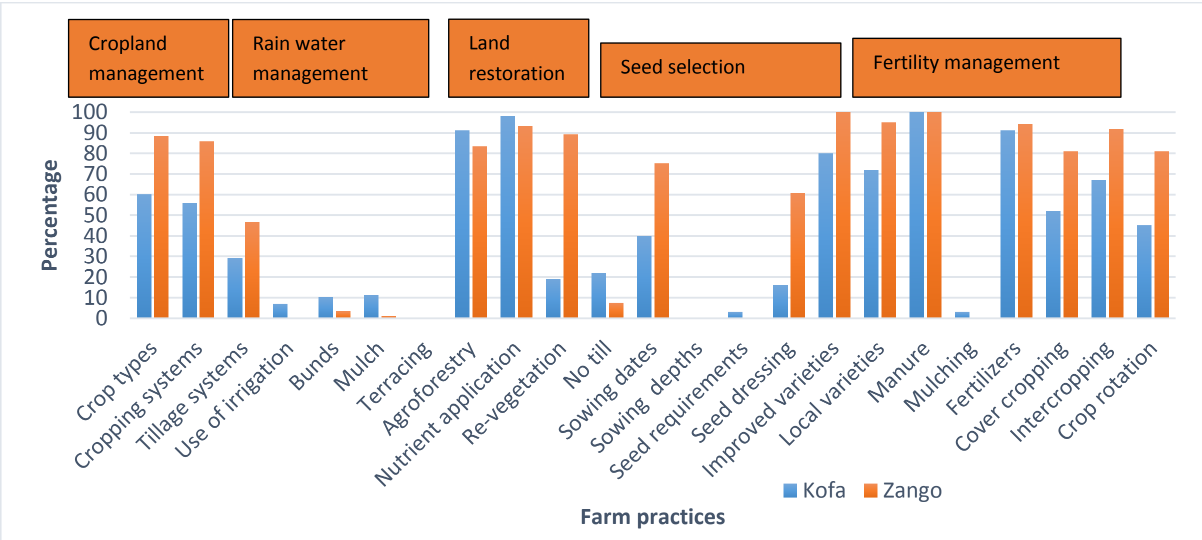


Figure 5.7 Current farm practices employed in Zango (n=120) and Kofa (n=100).

5.6 Survey II results - Theory of Planned Behaviour

5.6.1 Variability of determinants across climate change adaptation behaviour

The descriptive statistics of the Theory of Planned Behaviour model of climate change adaptation practices are listed (Table 5.6). The mean responses for all the variables were positively scaled. This suggests that most households have positive attitudes and intentions and received social pressures to adapt to environmental challenges. However, the positively skewed perceived behavioural control showed the likelihood of barriers hindering the households from adapting to climate change in their farming practices. Cronbach's alpha coefficients showed the level of internal reliability in the responses to questions. An alpha coefficient greater than 0.7 was considered suitable (DeVellis, 2012). Only Attitudes towards behaviour had Cronbach's alpha coefficient > 0.7 in the two communities, which suggest that the households responded and ranked the questions related to attitude consistently.

Table 5.6 Descriptive statistics of TPB components for climate change adaptation behaviour (Zango-n=86; Kofa-n=68).

TPB* Variables	**Items composition**	**Mean**		**SD**		**Cronbach's alpha**	
		Zango	Kofa	Zango	Kofa	Zango	Kofa
Attitudes	Mean of 3 items	7.91	7.51	2.04	2.26	0.80	0.81
Subjective norms	Mean of 3 items	7.37	7.06	2.00	2.27	0.47	0.57
Perceived behavioural control	Mean of 3 items	5.93	6.21	1.49	1.98	0.34	0.43
Behavioural intention		2.76	2.87	1.07	1.01		

TPB – Theory of Planned Behaviour; SD – Standard Deviation
*The attitudes, subjective norms, perceived behavioural control and intention measures were rated on Likert and bipolar adjectives scales from one to four. Higher figures indicate more positive responses.

5.6.2 Multiple regression analysis of climate change adaptation intention

A multiple linear regression was carried out to assess the TPB model for climate change adaptation behaviour to predict the main determinant of climate change adaptation from attitude, subjective norms and perceived behavioural control. Also, to test whether climate change perception predicts adaptation behaviour. The reliability of the TPB questions was verified using Cronbach's alpha coefficient. The significance level was set at 0.05.

The intention of households to adapt in the two communities was predicted from direct attitudes, subjective norms and perceived behavioural control. The regression model explained about 61% and 55% of the variance of the intention to adapt in Zango and Kofa respectively (Table 5.7).

Table 5.7 Regression model for Zango and Kofa for climate change adaptation intention.

Community	**R^2**	**Adjusted R^2**	**MS residual***	**F (significantly different from zero)**
Zango	0.65	0.61	0.452	(3, 82) = 40.73
Kofa	0.61	0.55	0.452	(3, 64) = 29.38

*$p < 0.05$

Nevertheless, one predictor (attitude towards behaviour) contributed significantly towards the prediction of adaptation intention to climate change in the two communities and subjective norm also contributed significantly to adaptation intention in Kofa and not in Zango (Figures 5.8 & 5.9).

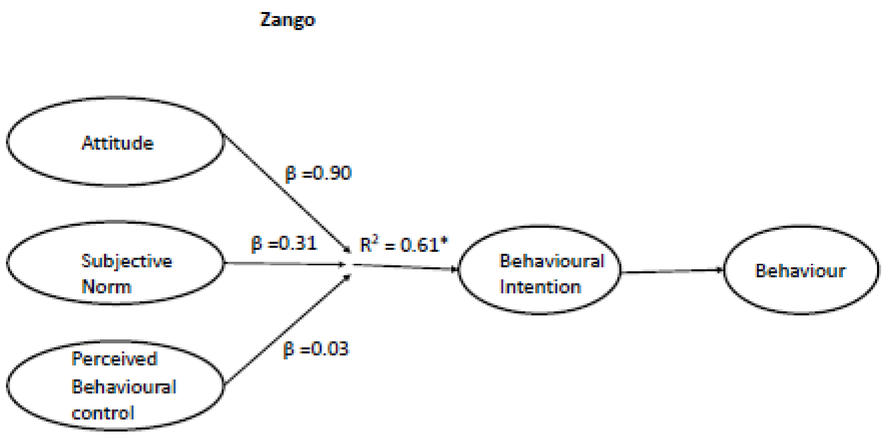


Figure 5.8 Theory of Planned Behaviour model for climate change adaptation for Zango (*$p < 0.05$).

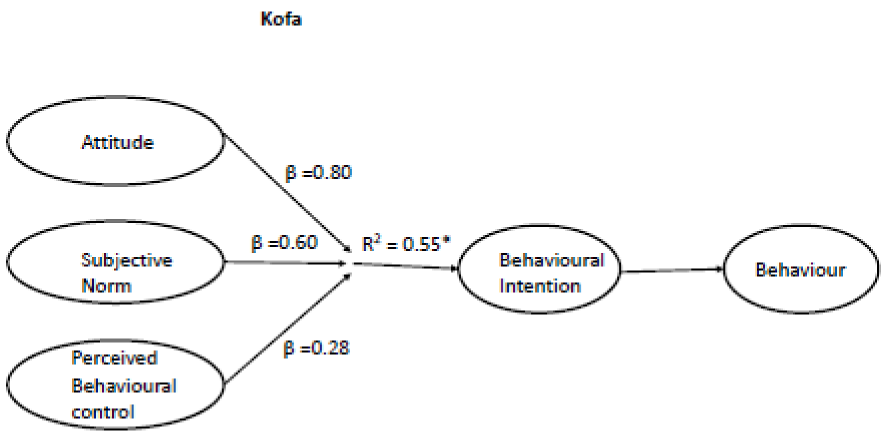


Figure 5.9 Theory of Planned Behaviour model for climate change adaptation for Kofa (*p < 0.05).

Some adaptation practices important for drylands resilience were visibly absent in both communities (Figure 5.7). Hence, updating farming households' knowledge and improving all the three determinants of adaptation behaviour would be a valuable part of extension training.

5.7 Discussion

This chapter tested the usefulness of the TPB in eliciting climate change adaptation intention against the backdrop of climate change perception by Zango and Kofa smallholders. As anticipated, the TPB model accounted for a substantial variance in the association amongst subjective norms, attitude and perceived behavioural control and intention. This suggests that attitude towards behaviour and subjective norm were the most important determinants of intention to adapt to climate change in Kofa while only attitude was important in Zango. This may arguably be due to households' willingness to adapt but constrained by lack of information and awareness about climate change. Thus, households were more likely to integrate adaptation into their farming practices when they perceive climate change to be happening. The significance of perception (Weber, 1997; Grothmann and Patt, 2005) has been demonstrated in some climate change adaptation studies.

Subjective norms (Masud *et al.,* 2016) and perceived behavioural control (Lin, 2013; Masud *et al.,* 2016) were argued to be the significant determinants of adaptation to climate change in other studies. Although the subjective norms and perceived behavioural control were skewed positively in this study (Table 5.6), only subjective norm was significant in determining intention in Kofa while both factors were not considered significant determinants of climate change adaptation in Zango. Findings also suggest that for climate change adaptation behaviour, intention may not be considered completely within households' attitudes alone and that a lack of available and up to date extension information could contribute to poor awareness, which in turn could limit adaptation to climate change.

The level of trust in one's effectiveness will affect the intention to cope with a given circumstance. While people tend to avoid or fear unfavourable events they perceive to exceed their adaptive capacities, they often engage and have confidence in activities they feel competent about handling even if it is potentially threatening (Bandura, 1977). Burch and Robinson (2007) argue that high perception of climate change risks could lead to interest in adaptation or mitigation as an understanding of the benefits of such action is necessary for a behavioural change. This is demonstrated in the findings of this study as climate change perception was considered an important driver of adaptation behaviour by the respondents in the two communities. Hence, a 'community that perceives a high level of risk might also utilize the social forces that encourage and reinforce adaptive or mitigative behaviour' (Burch and Robinson, 2007: 313).

Similarly, intentions are, to a reasonable extent, expected to result in the performance of a behaviour, as Ajzen (2015: 125) asserted that:

"the more favourable the attitude and subjective norm with respect to engaging in the behavior, and the greater the perceived control, the more likely it is that a person will form an intention to perform the behavior in question".

This aligns with results from this study which show positive values for intention to carry out the adaptation behaviour. However, available evidence across a range of disciplines shows that 'human intention to do something does not always indicate that they will [take action]' (Niles *et al.,* 2016: 292). In the same vein, other studies for sub-Saharan Africa (e.g. Bryan *et al.,* 2009) found that though respondents perceived climate change to be happening, perception did not lead to change in practice to adapt. This was argued to be due to certain barriers, such as lack of access to credit and land.

Respondents in Zango community- the drier community, perceived higher sunlight intensity to be increasing, while Kofa that experiences relatively more rainfall, perceived rainfall to be decreasing. Previous climate change perception studies for the Nigerian Savanna (Tambo and Abdoulaye, 2013) show similar trends in perception, where the perception of rainfall and temperature differed according to Agro-ecological zones (AEZ). Results from the scatter plots show outlier households away from the groupings, such as respondent ID 32, ID 3, ID 4, ID 58, ID 109, ID 5 and ID 112 for Zango (Figure 5.5) and ID 92, ID 77, ID 81 and ID 98 for Kofa (Figure 5.6). This suggests that such analysis can identify non-performing households who have been left behind in the perception of environmental change and adaption of good farming practices, as indicated by few assets and livestock, few crops, small land sizes and lack of access to extension for most of these groups. Similarly, those households who are represented at the forefront of the groupings (Figures 5.5 & 5.6) are demonstrating that they are sensitised to climate change and are adapting more successfully, as indicated by their higher assets (ID 116, ID 117, ID113, ID 106, ID 102, ID 54, ID 11 and ID 100, ID 97, ID 96, ID 68, ID 43 and ID 39 for Zango and Kofa respectively). These households may contain lead farmers for an improved farmer to farmer extension or community self-help. However, in stating these observations, these characteristics are not exclusive to these groups and the available data is insufficient to validate these findings. In addition, further probing of the available data using Chi-Square analysis did not also show any unique feature that could describe the outlier group, which may be serendipitous.

Taking the case of perception about technology, Meijer *et al.* (2015), for instance, argues that farmers' perceptions about a technology, closely relate to the knowledge of the technology. Whilst knowledge deals with facts about the new technology and how it functions, perceptions, however, is concerned with the views held by farmers on the technology, based on their needs and initial experiences which may not be realistic (Meijer *et al.,* 2015).

On the other hand, perceived behavioural control is achieved when there is a complete belief that the required resources and privileges to carry out an action is possessed (Ajzen, 1985). This implies that the more the person perceives control over a certain behaviour, the more the motivation to perform that action (Madden *et al.,* 1992; Ajzen, 1985). Poor perceived behavioural control recorded in this study may signal limited motivation to carry out the adaptation behaviour. Contrarily, when intentions are held constant, it is more likely to perform a behaviour as 'PBC increases' (Conner and Armitage, 1998).

It is highly likely that intention when strong indicates willingness to make effort to perform a behaviour, that is the stronger the intention, the more likely it is to perform the behaviour (Ajzen, 1991; Dang *et al.,* 2014b). For example, if two people have equal intentions to 'learn to ski, and both try to do so, the person who is confident that he can master this activity is more likely to persevere than is the person who doubts his ability' (Ajzen, 1991: 184). Hence, it could be argued that if smallholders believe they have the capacity to carry out adaptation behaviour, they will likely carry out the adaptation behaviour.

Perceived behavioural control (PBC) and intention must be measured in the context of the behaviour intended for them to be valid (Ajzen, 1991). It can reasonably be argued that climate change perception, the presence of PBC, and attitude towards behaviour can lead to adaptation behaviours. Although Conner and Armitage (1998) argued that the link between behaviour and PBC is not a straightforward one. As there is likelihood to engage in desirable behaviours that one has control over while one is unable to carry out a behaviour with no control over. It is at the perception stage that the unique factors that influences one person to carry out a behaviour of interest and the other to act differently can be learned (Ajzen, 1991).

Contrary to findings from previous psychological studies that attitude does not influence people's behaviour (Wicker, 1969 cited in Terry *et al.,* 1999), this study found attitude to be a key determinant of behaviour. This corroborates findings in a study of understanding farmers' climate change adaptation intention in the Mekong Delta (Dang *et al.,* 2014b) where it was argued that farmers are most likely to have an intention to adapt when higher risks of climate change and adaptive capacity are perceived. However, farmers become less likely to adapt when subjected to wishful thinking, fatalism, and denials of the risk of climate change (Dang *et al.,* 2014b). Apart from attitude towards behaviour, subjective norms and perceived behavioural control, 'anticipated affective reactions' were found to be important determinants of behaviour in previous studies (Richard *et al.,* 1996).

5.8 Chapter summary

Adaptation to climate change reduces vulnerability and improves the food security of households. As other studies argued that perception alone does not lead to adaptation but the availability of capacity to adapt helps in the adaptation process (Grothmann and Patt, 2005). The theory of planned behaviour has allowed us to predict intentions and behaviour towards adaptation to climate change. However, intention on behaviour in itself is not enough to influence a behaviour in the absence of the ability to carry out that intention that is, people only act on their intentions when they have enough control over the particular behaviour (Ajzen, 2015). Hence, finding means of improving the three behavioural determinants would be very useful. The multiple regression model explained (for Zango = 0.61; for Kofa = 0.55) of the variance in climate change adaptation intention ($p < 0.05$). Although mean values for subjective norms and perceived behavioural control were positively skewed, subjective norm was a significant predictor of intention in Kofa but not Zango, while perceived behavioural control was not a significant predictor of intention to adapt to climate change in this study. The findings from this study could support policy makers to design programmes that will influence attitude towards an intention to adapt to climate change, thus reducing the impact of climate change and degradation to household livelihoods. We now move to stakeholder engagement on GAPs in the study communities in the next chapter.

CHAPTER SIX

Delphi study and stakeholder engagement

Different stakeholders were engaged beyond farmers' level and the approaches to eliciting their views include Delphi study; extension and research interviews. This chapter resulted in 2 articles, 1 published and the other prepared for publication as follows:

1. Jellason, N.P, Baines. R.N. and Conway, J.S. (2017) A Delphi approach to the selection of Good Agricultural Practices (GAPs) for resilience enhancement for dryland farmers in North-western Nigeria. Journal of Food Science and Engineering 7 (8) 383-395. doi: 10.17265/2159-5828/2017.08.002.

2. Effective extension and farmer engagement: A case of Zango and Kofa communities in North-western Nigeria.

The objectives of this chapter are to:

- seek expert opinion on whether the Good Agricultural Practices (GAPs) selected from scientific review were appropriate for tackling environmental challenges of agriculture identified in the study communities;
- explore existing extension arrangements in Zango and Kofa communities in North-western Nigeria and to seek to understand current knowledge of GAPs amongst extension agents and stakeholders working with farmers in those communities.

6 Delphi technique

In conservation science studies, expert knowledge has been found to be useful to overcome problems of data unavailability (Kuhnert *et al.*, 2010) and the exigency around decision-making on conservation issues (Martin *et al.,* 2012). An expert, according to Martin *et al.* (2012), *'is someone who holds this knowledge and who is often deferred to in its interpretation'*. The Delphi technique, on the other hand, refers to an iterative process of seeking expert opinion through the use of well-crafted questionnaires (Hsu and Sandford, 2007; Yousuf, 2007; Robson, 2011; Rand Corporation, 2017) to form a consensus on a certain topic that is still valid (Landeta, 2006). The method is not only a data collection process, but provides an opportunity for a group of experts to brainstorm over a complex problem (Linstone and Turoff, 2002). Despite similarity with focus group discussions in eliciting group responses as opposed to individual response (Okoli and Pawlowski, 2004), there are slight differences as expert panels are formed in a structured way (Fisher, 2010) to seek clarity on reasons for a divergent opinion (Hsu and Sandford, 2007). While in Delphi studies there is the independence of expert opinions, dominant participants influence each other in focus group discussions in a group dynamic. Also, individuals in each round of Delphi can be drawn from a wider location and do modify their views based on feedback received.

No consensus has been reached in the literature on the number of participants in a Delphi panel (Hsu and Sandford, 2007) as the minimum number of panel members is dependent on the study design (Yousuf, 2007). Panels can be made up of 15 to 35 participants in some cases (Gordon, 1994), while in others it could range from seven (Chu and Hwang, 2008) to 115 panellists (Grundy and Ghazi, 2009). Delphi methodology's strengths lie in the fact that it does not require participants to be brought together and its democratic nature which helps in bringing together mutual knowledge in the discipline, hence, 'facilitating inter-professional communication' (Robson, 2011). Despite these strengths, the lack of understanding of the consensus-making process leads some to question the rigor in this methodology (e.g. Robson, 2011).

The overall aim of using the Delphi technique in this study was to seek expert opinion on whether the Good Agricultural Practices (GAPs) selected from the scientific review were appropriate for tackling environmental challenges of agriculture identified in the study communities. Other objectives included:

- To understand from expert perspective if farmers in these areas already use these GAPs and if not whether they need support to adopt and adapt the GAPs;
- To explore from experts' view if farmers in these regions generally need further training on the GAPs and if yes what methods are appropriate for the training;
- To ascertain whether the selected GAPs have the potential for sustainability and greenhouse gas mitigation in those areas.

6.1 Materials and methods I

A baseline survey was initially carried out to understand the current use of GAPs in the study communities (Section 5.5.2). The Delphi technique was then used to seek expert opinion on the usefulness of the GAPs chosen and on how they could result in resilience enhancement of drylands agriculture.

6.1.1 Design of the Good Agricultural Practices (GAPs) action plan

A GAPs action plan was designed for sub-Saharan African dryland farmers to be used as a means of engaging with the farmers on how to remedy their dryland environmental challenges as highlighted in the baseline study. A detailed review of the literature as suggested by Hsu and Sandford (2007) was done around GAPs for drylands management as the first round of the Delphi technique. This is because it is suggested that if an existing list of the items of interest is available, the first round can be 'by-passed' (Yousuf, 2007). Hence, making the methodology a potentially two-round Delphi process (Vidal *et al.,* 2011). Most Delphi studies do not exceed two rounds, as experts are busy and unwilling to participate in more rounds (Wentholt *et al.,* 2010). Based on available evidence from literature, GAPs for tropical drylands management were selected and linked to the associated benefits of adoption. The study was carried out in the context of tropical drylands to allow for high response rate, as most experts at the second round signified a lack of specific knowledge of northern Nigerian drylands. Since it is important to contact experts at least twice with the same questions in order to review their previous responses based on the responses of other experts in the panel (Landeta, 2006), two rounds of the Delphi were carried out.

The GAPs action plan questionnaire contained a total of 19 main questions with 6 questions having sub-sections. The questions were on topics related to:

i. GAPs overview.
ii. Training on GAPs.
iii. Suitability of GAPs for soil fertility management.
iv. The importance of GAPs for degraded land restoration.
v. The importance of GAPs for rainfall and drought management.
vi. The importance of GAPs for pests and diseases management.
vii. Suitability of GAPs for sustainability and GHGs mitigation.
viii. Additional GAPs suggested.
ix. Area of specialization of the respondent.
x. Current sector respondent is employed in and;
xi. Respondent's interest to participate in the study and previous experience on GAPs training.

Based on claims in the literature (Appendix 1), selected practices were presented to the experts, along with 4 point Likert scales (Lozano *et al.,* 2008) where experts could agree or disagree with the GAP chosen. A further section allowed them to justify scoring and offer alternatives appropriate for ranking. Hence, the Delphi survey was carried out to verify the GAPs chosen so that the training and action planning intervention will be evidence-based. Being a methodology that seeks expert opinion based on their experiences and expertise and not aimed at generalizing findings, the results of the Delphi were subjected to descriptive statistical analysis (Okoli and Pawlowski, 2004). The summary of the rounds is presented (Table 6.1).

Table 6.1 Delphi rounds.

Round I	Review of literature on GAPs for dryland management.
Round II	Experts' ranking of the GAPs and their suitability for GHGs mitigation and approach to training with suggestions given.
Round III	Feedback from reviewing the second round with suggestions given until consensus is reached.

6.2 The approach to the Delphi technique

The Delphi technique took the following procedure:

6.2.1 Expert selection and sampling

A panel of experts were invited to take part in a Delphi study (Table 6.2) to gather evidence on which GAPs were needed by the target farmers, their opinions on farmers' current knowledge of GAPs, whether training is needed for dryland farmers, and the importance of incorporating farmers' input into the design of the training on the GAPs selected. Experts were also requested to comment on the ideal methods of training, and suitability for tackling the environmental challenges faced by farmers in sub-Saharan African drylands which include:

I. Soil fertility problems.
II. Land degradation.
III. Low rainfall and drought.
IV. Pests and diseases.
V. Greenhouse gas emission.

Random selection was not used in selecting the panellists and hence sample representativeness cannot be assured (Soon *et al.,* 2012). In most Delphi studies, non-probability sampling is accepted to solicit expert opinions (Hasson *et al.*, 2000, Powell, 2003). Selection of experts was based on the following criteria:

- Researchers in conservation agriculture disciplines and drylands whose research papers have previously been used by the researcher.
- Practitioners in the field of conservation agriculture in Africa.
- Professionals co-nominated by participants in the study (Scapolo and Miles, 2006).

In total, 63 experts were invited through emails to participate in the study where consensus was reached after round 3 which formed the methodology (Wentholt *et al.*, 2010; Vidal *et al.*, 2011).

Table 6.2 Characteristics of the GAPs experts in the Delphi rounds.

	Round II (n=11) Number of experts (%)	**Round III (n=12) Number of experts (%)**
Area of expertise[2]		
Agronomy	3	3
Soil Science	3	4
Plant Science	-	1
General Agriculture	4	5
Biology	1	2
Environmental Science	5	6
Others[a,b,c,d,e,f,c]	1	4
Employment		
University/College	4(36)	5(42)
Research Institution	-	1(8)
Government Department	1(9)	1(8)
Private company/business	3(27)	1(8)
Multinational organisation	1(9)	-
Others[1,1,1,2,1]	2(18)	3(25)
Interests in participating		
Yes	6(55)	12(100)
No	1(9)	-
Maybe	4(36)	-

Environmental social science[a]; Land management[b]; Geography[c]; Environment & development[d]; Extension[e]; Soil & water management[f]; Non-Governmental Organisation[1]; Freelance consultant[2]

The literature review to develop the questionnaire served as the first round followed by the first questionnaire sent to the 38-panel members to seek their opinions (Table 6.3).

Table 6.3 Participants in the (GAPs) for tropical drylands Delphi studies.

Delphi panel	**GAPs experts invited**	**Experts responded**
Invited (Round II)	38	11 (29%)
Round III	11+14(recommended)	12 (48%)

[2] There were options for multiple choices of areas of expertise, so percentage may not necessarily sum up to 100.

6.2.2 A survey of GAPs experts

Most of the experts are from a University/College background, research and development professions across Africa and Europe with diverse fields of expertise as they were advised to select more than one option where applicable (Table 6.2). Experts in the rounds 2 and 3 are mostly from agronomy, soil science, general agriculture and environmental science disciplines. Hence, their opinions on the selected GAPs are highly valued as they have long years of experience and knowledge of these GAPs and their applicability.

i. Round I

Findings from the review of the literature on the items to be included show varied GAPs for low rainfall management, soil fertility management, pest management, degraded land restoration and different methods for extension (Figure 6.4). This is because first rounds mostly serve to specify matters to be tackled in subsequent rounds (Powell, 2003).

ii. Round II

The round 2 of the Delphi consisted of a 4-point-Likert scale survey questions from a review of the literature (Hsu and Sandford, 2007). This was to reduce the number of iterations. A potential for bias could arise due to limited options available (Keeney *et al.,* 2001). However, spaces were given for respondents to suggest additional GAPs for inclusion in the action plan with other relevant comments (Scheibe *et al.*, 2002). Questions for this round were sent out to all the experts invited so that they could rate the selected GAPs, suggest any need for further training and advocate the best approach to training. Experts were required to select and rank the suitability of the GAPs for water, soil fertility, pest and diseases management and degraded land restoration. Options were rated on a 4-point Likert scale based on (1 = "Strongly Disagree" and 4 = "Strongly Agree"). The options were 'forced' for experts to make specific choices as there was no option of "Neither agree nor disagree". Furthermore, positive responses and negative responses were grouped together and plotted in a bar graph. It was requested that responses be returned to the researcher as soon as completed for further review and analysis. Suggestions for improvements solicited (Table 6.4) with email reminders sent to remind those yet to return filled questionnaires to do so.

iii. Round III

Responses from the round 2 were put together and suggestions from experts were incorporated to increase the level of consensus in the third round, the response rate and the strength of the action plan. Response rate at this stage increased from 29 % in the first round to 48 % in the second round. Practices that received less than 50 percent consensus in the second round were dropped such as ‘intensive control livestock grazing (more livestock)’ which was replaced by ‘sustainable pastoralism’ as this better-reflected smallholder practices. However, the study did not focus on this practice because the communities do not partake in it, so it was dropped. Other practices included in the mitigation section of the questionnaire comprised: ‘intercropping legumes with other crops’ and ‘use of cover crops’ as suggested by the experts. Results for rounds 2 and 3 are analysed and presented (Section 6.3.2). Therefore, by building experts’ suggestions into subsequent rounds, it helped in building confidence in the study (Landeta, 2006).

All items that reached consensus (70 percentage) at this stage were used for the action plan training for northern Nigerian dryland farmers. All the panel members that responded to the round 3 indicated interest in having the final report of the Delphi study to be shared with them.

iv. Limitations of the Delphi methodology

Despite the numerous advantages of employing the Delphi technique to collect data in the form of expert opinion, which include cost-effectiveness and time-saving, it is not devoid of limitations. Some of the limitations include: influencing consensus in some cases (Yousuf, 2007), the process of expert selection could be misleading, and due to the small sample size, findings cannot be generalisable. Hence, the value of the Delphi technique is in the ideas generated (Gordon, 1994), and the outcome is as good as the quality of the panel members, since it is opinion based (Yousuf, 2007).

Socio-economic and cultural aspects of GAPs adoption and more focus on crop with less emphasis on animals were some of the issues raised during the Delphi rounds that needed to be addressed. Some terminologies such as ‘sustainable’, ‘appropriate’ were said to be vague by some panel members and hence defining them could be crucial in order to avoid bias (Kuhnert *et al.,* 2010). The technique is mostly argued to be oversimplified as it is being viewed by non-expert researchers as an easy method for data collection thereby missing the rigour it entails. Lack of prompt feedback to participants on the findings from the use of Delphi normally discourages participants from participating in future studies making them feel used with nothing in return (Landeta, 2006).

v. Potentials of the Delphi methodology

Despite the shortcomings of the Delphi technique, it has value in its effectiveness in organising opinions without physically bringing respondents together due to resources constraint (Hasson, *et al.,* 2000; Steinert, 2009). Hence, the application of the methodology in this study. Group decision-making is more superior to aggregate individual responses in Delphi studies. This is because it provides rich data from multiple iterations and revision of responses informed by feedback, while also maintaining the anonymity of responses (Okoli and Pawlowski, 2004). Hence, bringing the responses close to reaching a consensus after each round. However, not being in same room avoids dominance by some individuals.

6.3 Results and discussion I

This section presents results and discussions on the GAPs selected for training and the level of consensus reached each round.

6.3.1 Characteristics of expert participants

Experts in the Delphi study cut across different disciplines which helped in shaping the responses. Most experts are from environmentally related disciplines followed by general agriculture, agronomy, and soil science. Detailed characteristics of the expert respondents are highlighted in Table 6.2.

6.3.2 GAPs overview

Only three items reached consensus in the second round on the importance of the GAPs. However, after suggestions for improving the questionnaire were incorporated for the third round, four items out of six reached consensus, which is one item over the second round (Figure 6.1). This implies that most experts agreed that GAPs are important for solving soil fertility and drought challenges in tropical drylands and can also support pest and disease management and degraded land restoration. Percentage consensus dropped in the third round for 'Farmers already use GAPs' item, which could be due to the responses from the new panel members who may possess divergent views on this item.

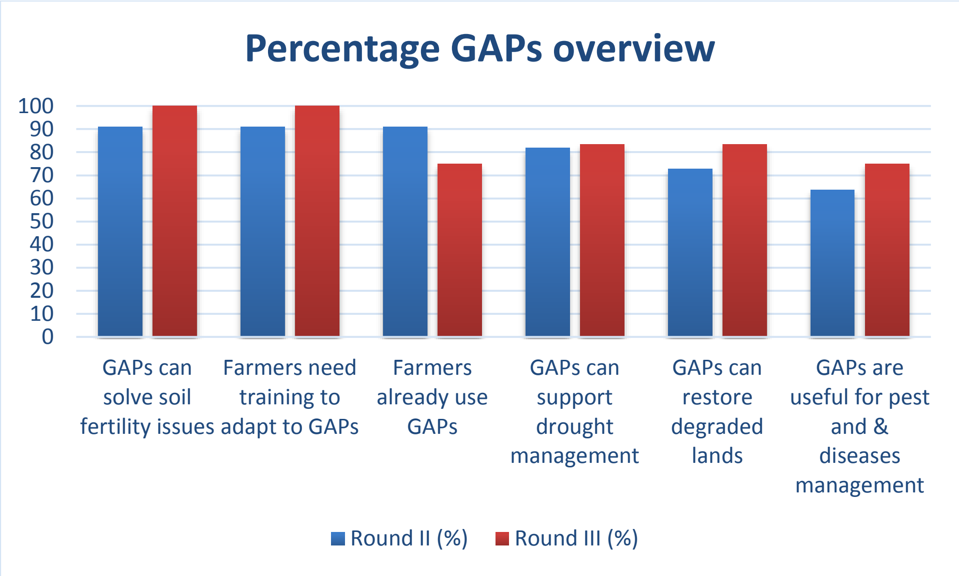


Figure 6.1 Good Agricultural Practices Overview Round II (n=11), Round III (n=12).

Suggestions for improvement of action plan rounds II and III.

Table 6.4 Suggestions for improving the action plan from round II.

Practice	**Expert (E)**	**Suggestions**
Practices under GAPs overview	E2	There is need to indicate crop specific GAPs for that region.
	E3	Drought management requires more than GAPs especially in the dryland where water is highly insufficient.
	E4	More GAPs need to be developed
	E5	GAPs should first be defined and secondly understood and implemented properly
	E9	GAPs in drylands must not focus on crop farming only; mobile pastoralism as a livelihood strategy and production system is central to reversing land degradation in drylands.
	E10	Complementary practices are necessary to integrate with GAPs including good extension methods
Training on GAPs	E3	Farmers' knowledge should be considered in GAPs training as they possess more knowledge than expected.
	E9	All training methods are relevant not as stand-alone but integrated where necessary.
	E11	A combination of all these training methods are important, there is no one best method.
Farmer to farmer knowledge exchange	E3	This can be effective as farmers have been learning from each other for generations now.
GAPs for low rainfall and drought management	E6	Zai is important but labour intensive. -And small-scale irrigation depends on the availability of water for irrigation.
GAPs for soil fertility management	E1	Cover crops with intercropping legumes with other crops are very important here. Incorporating crop residue into the soil is also very important here.
GAPs for pests & diseases management	E6	Practices should be a combined set of technologies and not separate entities.
	E6	It should read 'destruction of diseased crop residue' not 'destruction of crop residue'.
GAPs for degraded land restoration	E9	Too focused on crop production and missed livestock production which is a key production form in these marginal areas.
	E10	Natural regeneration is an important practice here.
GAPs missed out	E4	Appropriate agronomy (weed management, plant spacing).
	E6	Precision planting and early planting

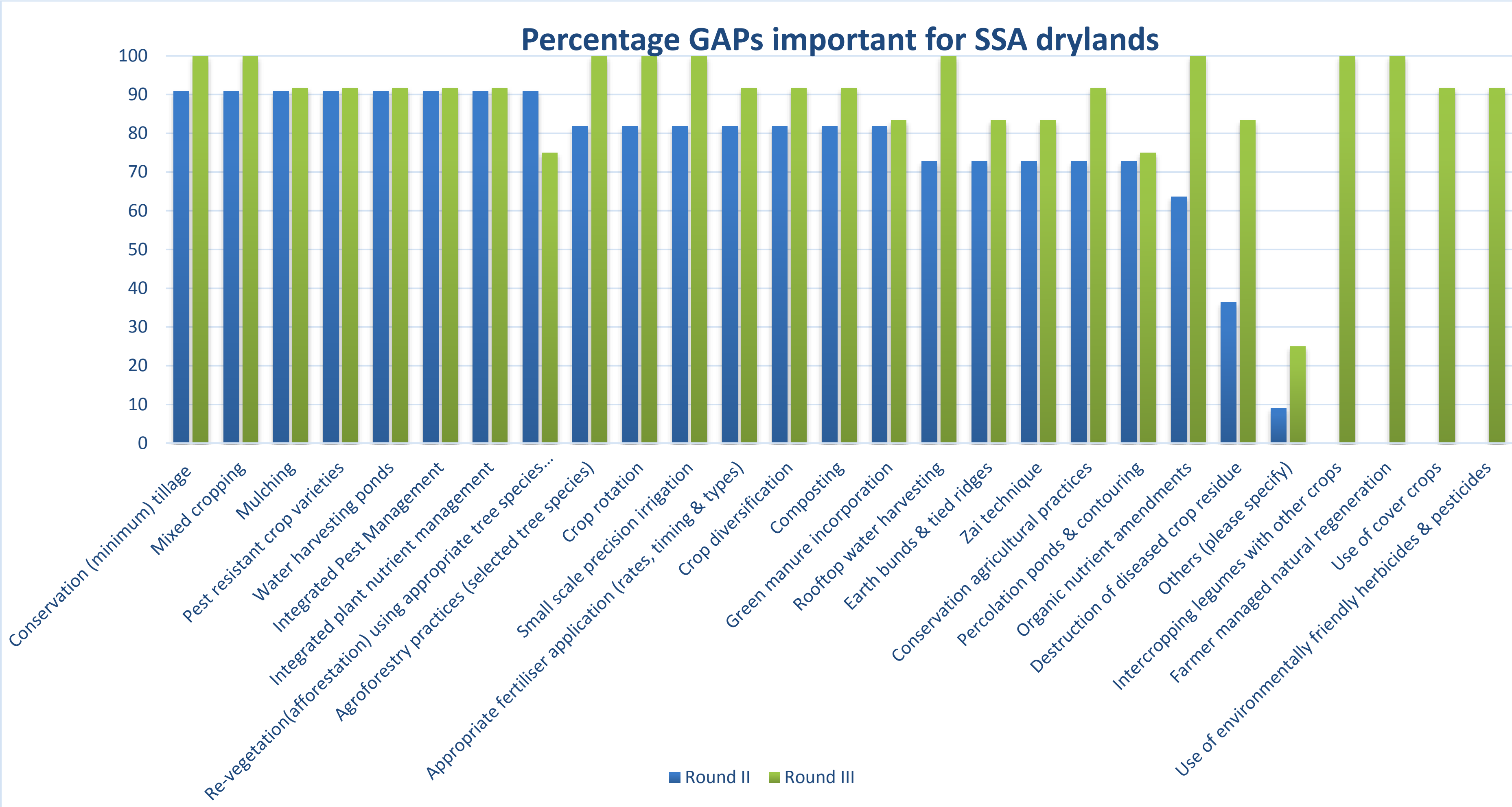


Figure 6.2 Important Good Agricultural Practices in sub-Saharan African drylands assessed using the Delphi technique.

Table 6.5 Suggestions for improving the action plan from round III.

Practice	**Expert (Ex)**	**Suggestions**
Practices under GAPs overview	Ex11	**-Some extreme events or years require external support.**
	Ex4	**-Drylands deal with extremes that are beyond the capability of these farmers. So, the need for additional support.**
	Ex3	Extension is needed for more enlightenment and pest and diseases' symptoms, management and ecology.
	Ex1	-There is knowledge of GAPs, but potentials exist for improved applications.
GAPs for soil fertility management	Ex7	-Leaving green manure on the surface is better than incorporation.
	Ex7	-Mixed cropping should be crop specific.
	Ex4	-Sustainable Pastoralism should be defined.
GAPs for rainfall and drought management	Ex12	-With the availability of water.
	Ex3	-Agroforestry should be included.
GAPs for pests & diseases management	Ex4	-Use cover crops. -Use natural enemies.
	Ex3	-Herbicides and pesticides should not be encouraged.
GAPs for degraded land restoration	Ex4	-If the production of mulch fits within the farming system.
GAPs potentials for GHGs mitigation	Ex11	-Earth bund and tied ridges may be in the long-term.
	Ex3	-Re-vegetation should be specific either afforestation or any other practice. -Zai is labour intensive as such its socio-economic benefits should be ascertained first.
	Ex2	-Some of the practices may not lead to GHGs mitigation.
	Ex9	-Minimum tillage and intercrop should not be separate from conservation practices to avoid duplication.
Additional practices for resilience enhancement	Ex6	-Cropping systems are better than component technologies.
	Ex5	-Community time-tested and tried indigenous practices and knowledge. -Gender should be mainstreamed in the practices.

***Statement in bold affirmed the need for additional training on GAPs in the study areas.**

6.3.3 The Delphi surveys

In table 6.3 the number of experts invited to participate in the Delphi study and the response rate at each round is indicated. The response rate for second and third rounds (29 and 48 percent respectively) was typical of responses in Delphi studies (Wentholt *et al.,* 2010). In the second round, two experts declined to participate, though one requested to be reminded again but did not respond. There was no information from the other 24 experts invited. From the 11 responses in the second round, 14 additional names were suggested by the participating experts to be invited making the number of invited experts for the third round to be 25. However, despite sending email reminders on two occasions to increase the response rate, only 12 experts responded to the third round that led to the development of the final results used for the farmer action plan. Responses are mostly at the discretion of respondents (Hasson *et al.,* 2000). Time constraint could be the reason for some respondents not responding as two respondents in the round II requested to be reminded for the round III to confirm availability to participate. Using Green's (1982) suggestion cited in: (Hsu and Sandford, 2007), the consensus in this study was taken to be 70 percent of respondents rating 3 or higher in a 4-point Likert scale.

6.3.4 Need for training on GAPs uptake and out-scaling to other communities

Under the GAPs overview (Figure 6.1), the statement on the need for further support for farmers to adopt GAPs in drylands through training and extension in the second and third rounds reached consensus. While in terms of the absolute ranking, in round II, 10 people out of 11 scored 3 and over and in round III, all 12 respondents scored 4 (100%). Hence, a consensus was reached from the second round on the need for training to be carried out thereby informing the training and action planning in the two study communities. All participants in both rounds II and III agreed that farmers should be trained on GAPs and that the local knowledge and socio-economic conditions of the farmers should be considered in the generation, piloting and out scaling of GAPs. This is in line with increasing emphasis on the need for effective knowledge sharing methods for environmental sustainability and management (Fazey *et al.,* 2013). Interestingly, a participant in round III (Ex4) asserted that drylands smallholders are faced with challenges beyond their capabilities, hence, the need for additional training for them to be adaptive, as demonstrated in the co-learning exercise reported in chapter seven.

Approaches to training (Figure 6.3) suitable for GAPs uptake were also ranked in terms of the number of participants who scored 3 and over. Consensus was not reached in round II in terms of an absolute number of responses on all items but all items reached consensus in round 3 except for 'training and visit'. Training and visit did not attain consensus at the round II with 5 out of 11 participants scoring 3 and over. However, it was retained at round III for the co-learning due to its importance despite only 8 (67%) out of 12 participants scored 3 and over in this item falling short of the 70 % consensus mark selected for this study. Use of anchor farmers suggested in the round II for inclusion did not attain consensus at the round III so it was dropped and not included for co-learning. Some panel members suggested that these training options could better be utilised in an integrated fashion as opposed to using them in isolation.

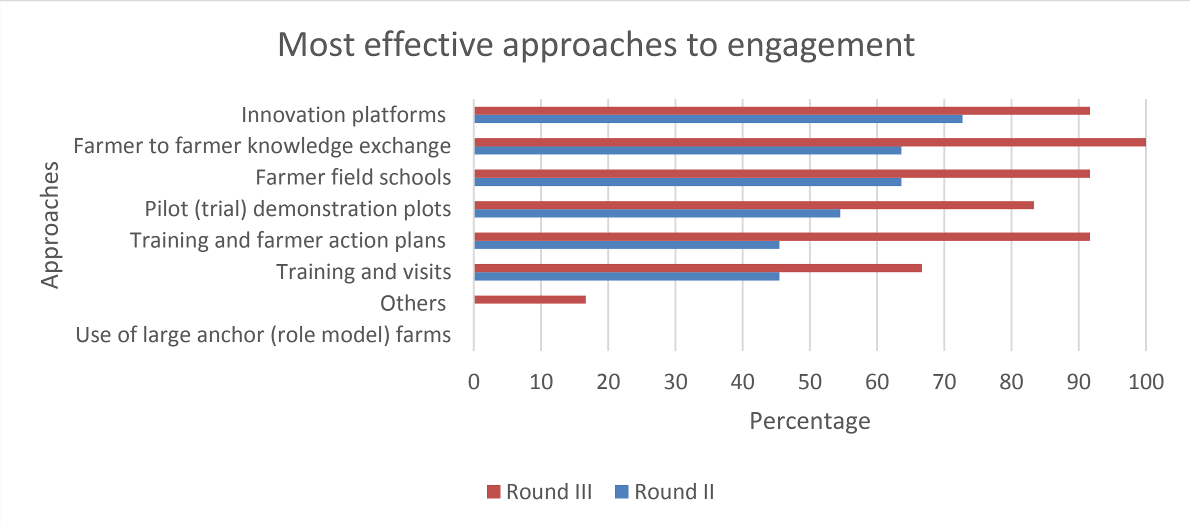


Figure 6.3 Expert opinions: Effective engagement of smallholders in up-taking GAPs adaptation requires a combination of two or more of the following approach (es) in developing countries.

6.3.5 GAPs on soil fertility management in tropical drylands

Practices for soil fertility management at round II all attained consensus apart from 'Intensive control livestock (more animals)' which recorded no consensus. An expert argued that more livestock keeping was an old approach to dryland management that has proven to be a poor practice, hence, it should be replaced by a more sustainable practice like 'Sustainable pastoralism'. While this is practiced in other sub-Saharan African drylands, it was not applicable to the northern Nigerian dryland, hence, it was dropped. For both rounds in terms of an absolute number of panellists, all retained practices scored 3 and over (≥82 %) thereby forming a consensus (Figure 6.2).

6.3.6 GAPs on degraded land restoration in tropical drylands

All practices selected attained consensus based on absolute number count for rounds II and III. The attainment of consensus from the round II of revegetation (afforestation) justifies the merit of this practice for degraded land restoration as advocated in the agroforestry literature (FAO, 2009). An expert in the round II (EX 9) argued that the GAPs were more centred on crop and neglecting livestock, which is a key production form in the marginal areas. Despite the focus of the research been on crop production, some aspects of livestock were later incorporated based on suggestions from some experts.

6.3.7 GAPs on rainfall and drought management in tropical drylands

The practices selected for low rainfall and drought management all attained consensus for the rounds II and III in terms of absolute numbers, they all recorded 3 and above in more than 70% responses on all items (Figure 6.2). Hence, they were used for the training.

6.3.8 GAPs on pest and diseases management in tropical drylands

All practices for pest and diseases management apart from the destruction of crop residues attained consensus with absolute numbers high (73 % and over) in both rounds II and III. However, a suggestion was made to modify 'destruction of crop residue' to 'destruction of diseased crop residue' which later attained consensus in the round III with 10 (83 %) out of 12 responses scoring 3 and above (Figure 6.2).

6.3.9 Potentials of the GAPs for sustainability and greenhouse gas mitigation in tropical drylands

In this section, all the practices highlighted above were assembled to understand their suitability for sustainability and GHGs mitigation. Although 'rooftop water harvesting' was suggested to be dropped after the round II for not been relevant for GHGs mitigation which was the initial goal, it is verified as a sustainability practice. Also, two additional practices were suggested for inclusion in the round III; 'Intercropping legumes with other crops', and 'Use of cover crops' with 'sustainable pastoralism' also replacing 'intensive control livestock grazing'. Being a 'Yes' and 'No' question, responses were presented in bar graphs since the level of measurement determines the type of statistical test to be employed (Hasson *et al.,* 2000). Hence, positive responses were used to decipher expert opinion on the suitability of the practices for sustainability and GHGs mitigation. The results show that agroforestry (FAO, 2009), conservation agricultural practices and 're-vegetation' had the highest positive values for the two rounds implying higher consensus as for the most important practices in terms of sustainability and GHGs mitigation in tropical drylands (Figure 6.4). It is increasingly important to pursue environmental conservation techniques in improving yield since incremental benefits of additional input has declined over the years (Vosti and Reardon, 1997a).

Figure 6.4 Expert opinions: GAPs in drylands with potential for sustainability and GHGs mitigation Rounds II & III.

Some of the responses recorded negative values as some panel members argued that the practices are context specific and dependent on land use. Hence, it may be difficult to generalise their application for promoting sustainability and greenhouse gas mitigation. We now look at farmer and stakeholder engagement through agricultural extension in the next section.

6.4 Farmer and stakeholder engagement

In the developing world, many of the poor inhabitants of rural areas rely on agriculture for their daily living. Hence creating dynamic 'rural communities founded upon prosperous farming' will play a critical role in alleviating the current sufferings of the poor (Dixon *et al.,* 2001:1). Extension in some form will be in the centre of this development, as for example extension in agriculture is aimed at facilitating the process of innovation uptake by farmers from research targeted at productivity and income improvement (FAO, 1997; Davis, 2008; Akinnagbe and Ajayi, 2010; Oladipupo *et al.,* 2014). Rural development is dependent on the decisions rural people make on daily basis (Dixon *et al.,* 2001); therefore, extension has the potential to aid the decision-making processes of farmers (Oladipupo *et al.,* 2014). Organizing farmers into groups or cooperatives has the benefit of ensuring easy access to extension on the one hand and more effective outreach on the other, leading to more input and other services (e.g. extension advice) (Bentley *et al.,* 2011). The emphasis in extension is now on knowledge facilitation and support for learning as opposed to technology transfer and training previously advocated under Training and Visits (T & V) as provided by the World Bank (Davis, 2008). In sub-Saharan Africa, poor extension amongst other factors has been widely acknowledged as a key constraint to improving agricultural productivity (Adenle *et al.*, 2017). Not least the sheer number of farmers per extension agent ranges from 1000 – 3000 and above.

Agricultural extension entails information dissemination, capacity building for farming households based on research and through the use of different methods of communication for good decision making (Koyenikan, 2008). In Nigeria, agricultural extension has not received the attention it deserves in recent years. Hence, its effect on farmer education and subsequent food security is not well felt (Donye and Ani, 2014). The failure of the top-down T & V (Anderson *et al.,* 2006; Davis, 2008) model of extension has necessitated a consideration of new approaches to farmer engagement that have elements of participation and that acknowledges farmer local knowledge and promotes farmer-to-farmer knowledge sharing (Reij and Steeds, 2003; Davis, 2008; Koyenikan, 2008).

Farmer-to-farmer knowledge exchange and government extension activities can also promote social capital (Islam *et al.,* 2013). As a result, mutual knowledge exchange using the participatory approaches of researcher to farmer and farmer-to-farmer have been found to be invaluable in the adoption of sustainable agricultural practices in certain situations (e.g Cerf *et al.,* 2000; Kilpatrick, 2002; Nerbonne and Lentz, 2003; Eshuis and Stuiver, 2005). Engaging in group activities between a researcher (facilitator) and farmers for their empowerment enables them to think and make decisions for themselves about their needs and how best to achieve them. This has been recognised to be important to farmers' success (Ingram, 2008). As such, in the period of uncertainty, improved extension services related to conservation practices will be invaluable (Reardon and Vosti, 1997b).

Previously, extension provision has been 'supply-driven' in a linear channel of technology dissemination from 'research → extension → farmers' (Akinnagbe and Ajayi, 2010). However, in sub-Saharan Africa recently, a shift towards farmer-led and demand-driven models of extension has been witnessed (Bentley *et al.,* 2011). This is due to the inability of the supply-driven and linear model to solve farmers' problems according to Akinnagbe and Ajayi (2010). It is in the light of this, that this section aims to explore existing extension arrangements in Zango and Kofa communities in North-western Nigeria and to seek to understand current knowledge gaps amongst extension agents and stakeholders working with farmers in those communities. From this, a new model of extension is proposed.

6.4.1 Developments in extension models in Nigeria

To understand the role of extension in enhancing farmer productivity, it is pertinent to explore the evolution of extension over the years. Extension is regarded as the vehicle for communicating research. Different models of extension have evolved over the years ranging from the traditional models of extension such as the Training and Visits (one-way) aimed at strengthening linkages between research and extension (Akinnagbe and Ajayi, 2010; FAO 2016a); to the use of new and modern channels of extension such as the use of TV, radio and Information and Communication Technology (ICT) (two- and multiple ways communication and conversation). In the past, extension approaches ranged from general extension-provided by government, University extension, project extension-to demonstrate benefits of a particular project over a period of time; commodity extension-focused on the production of a particular commodity (such as tea, rubber, cotton or coffee) mostly for export. Others include: T & V - patterned through a specific visit schedule to farmers and field staff training with some schedule of activities to be implemented and monitored fortnightly; last but not the least is the participatory extension that recognizes the active involvement of farmers (FAO, 1993) and the development of farmer field schools (FAO, 2016a).

Extension support has previously been either government, NGO or privately driven in Nigeria. Government or public extension are mainly delivered through the Agricultural Development Programme (ADP). The ADPs created in the 1970s and replicated across the 36 states including Abuja, were supported by donor funding and thrived very well while funding was maintained. The ADPs succeeded in implementing activities such as lead farmer identification and training on improved methods of farming, making available improved inputs and technology; establishment of demonstration plots and developing the capacity of lead farmers to teach other farmers (Mogues *et al.*, 2008). However, the gains of the ADP were short-lived, as critics argued that it over-emphasized the attainment of project implementation targets while neglecting the need for a sustainable service provision (Mogues *et al.*, 2008). Also, withdrawal of funding by the donors- principally the World Bank resulted in the crippling of the programme. The Training and Visit (T & V) model of extension developed by Benor and Baxter (1984) was the most popular due to the dominant support from the United States Agency for International Development (USAID), the World Bank and other donors (FAO, 1993) and was adopted in Nigeria in 1986 (Oladipupo *et al.*, 2014). However, it was less effective due to its ‘top-down’ approach, linearity and inability to factor specific farmer circumstances (Akinnagbe and Ajayi, 2010). Similarly, the T & V model of extension was also argued to be limited by inadequate budget, high-cost of execution, difficulty in ascribing impact, broad-based nature, poor accountability and high farmer to extension ratios (Anderson *et al*., 2006).

The new models of extension that introduced an element of participation by the users of extension being farmers and that encouraged a feedback loop and partnership among research, extension, and farmers has gained acceptability recently. This was due to poor utilization and impact of innovation from agricultural research institutes, which differs with field experience of the innovation (Oladipupo *et al.*, 2014). This led to models such as farmer field schools (experiential learning), field demonstrations, farmer-to-farmer extension and farmer exchange visits which are ‘demand-driven’. Other models include ‘farmer-group approaches’ where farmers assist each other to ‘learn and adopt’ (Akinnagbe and Ajayi, 2010). Farmer field schools (FFS) were originally from India following an outbreak of rice pest for promoting programs on integrated pest management (FAO, 2016a). While in Africa FFS received application in relation to food security, water and soil conservation, and animal husbandry (Davis, 2008). In these new models, there is a reversal of roles where research and extension are learning from farmers and farmers from each other (Akinnagbe and Ajayi, 2010). However, these demand-led model of extension were criticized for inclining towards the idea of private extension, which may not be affordable to rural farmers, as opposed to free public extension; and to the argument that farmers do not generally know what they don’t know, making the training and co-learning activity important.

Despite the benefits of the ‘farmer-led’ extension model, it is limited by the requirement by the government for a change in professional attitude and organizational structure from the old method to transition to this method of extension. This process requires training and cannot be achieved instantly (Akinnagbe and Ajayi, 2010). Other limitations of the farmer-led extension model include financial sustainability, logistics, domination of the participatory model by the village heads or wealthy individuals and neglecting the voice of the poor; the difficulty of farmers to accept information from fellow farmers as they do not believe anything new can emerge from their fellow farmers. This is because they believe only literate and intelligent people are perceived to hold new information such as external extension agents (Akinnagbe and Ajayi, 2010). Therefore, for a farmer-led extension to be established, there is a need for farmers to develop the capacity to voice their shared ‘demands and exert pressure on the system to deliver what they want’ (Rivera and Alex, 2004; Rosset and Altieri, 2017). There is also a parallel need for external ‘science-based’ advice to be incorporated into the model, especially where perceived new challenges are beyond the experiential scope of participating farmers.

Project experience of extension in the last few decades has brought to question the sustainability of public extension in promoting agricultural productivity and rural poverty alleviation (Saliu and Age, 2009). This they argued is due to a poor diagnosis of farmers’ needs, poor quality of technical and field staff, costly nature, lack of consultation with intended beneficiaries; poor political will and instability in policy. This is further worsened by high extension agent-farm family ratio, as indicated for some selected states in Nigeria (Table 6.6), which are in contrast to the recommended ratio of 1: 500 by the World Bank (Manyong *et al.*, 2005).

Table 6.6 Extension agent- farm family ratio in 27 States in Nigeria.

Source: Oladipupa *et al.* (2014)

The new model of extension proposed here is focused towards advisory service delivery in agriculture based on the ‘two-way’ communication that encourages knowledge co-production and sharing of evidence (Haug, 2000). In the light of the foregoing, this section is relevant due to poor knowledge of the capacity, performance and service quality of current extension systems in sub-Saharan Africa and in Nigeria specifically. Hence, such information is needed urgently to examine the performance of extension, its weaknesses and strengths to better position extension to achieve rural poverty reduction and livelihood improvement goals (Davis, 2008). This led to the proposed new model of extension in this study (Figure 6.6) and its efficacy based on results from stakeholder engagement.

6.5 Material and methods II

6.5.1 Research and extension in the study communities

To understand the nature of research and extension going on to support farmers in the study area, staff from one private research and two Government organisations were interviewed with staff from Agricultural Development Programme (ADP) separately in the two states of Kano and Katsina in North-Western Nigeria. The results of the interview are presented below:

6.6 Results II

Results from engagements with stakeholders undertaking research and extension in the catchment locations covering the two study communities are presented in the following sections and responses are presented based on case studies. To maintain confidentiality the interviewees (institutions) are labelled **A, B, C, D**, and **E**.

6.6.1 Case study of Government Research Organisation-1 (A)

This stakeholder operates from Kano state Nigeria and extending research to dryland areas. One person was interviewed in this institution aged 48, a Deputy Director with Ph.D. in Plant Breeding specializing in genetics and plant breeding with 24 years research experience working with farmers in both drylands of Nigeria and the Niger Republic. The institution's research focus was in crop and cropping systems, natural resources management and climate change; range and livestock management and livestock and natural resources economics. Institution **A** emphasized the use of collaborative research and development activities with the target farmers which is vigorously pursued as a means of engagement. Lack of training was highlighted as the major challenge to extension with funding for research and extension being 'grossly inadequate and trickles down slowly'. On the issue of extension ratio, the interviewee reported that the ratio of extension agents to farmers was 1: >500 and opined that the ideal ratio should be 1:200. In terms of research interventions and projects on sustainable dryland agriculture, this institution reported support with interventions around 'crop-livestock integration, intensification of cropping systems especially cereal-legume strip cropping for enhanced livelihood and food security' was in place. In terms of progress with the project on farmers' field, institution **A** responded as follows:

"Ongoing; achieving huge success. Strip cropping of cereals (maize, sorghum, and millet) and legumes (groundnuts, cowpea and soybean) resulted in yield increase of more than 100 %, coupled with enhanced quality feed for livestock-that produce manure for increased soil fertility".

Around challenges faced with the project, 'funding for scaling out is the major challenge' as reported by institution **A**. When participants' opinions were sought on what could be done to improve the challenges faced by the projects, **A** noted:

"Improved funding to ensure sustainable inputs (quality seeds, fertilizer, e.t.c.) supply and logistic support to reach out to many farmers in the Sudano-Sahelian (dryland) region".

6.6.2 Case study of Government Research Organisation-2 (B)

Institution **B** is in Kaduna state also extending research around Northern Nigeria with the dryland areas inclusive. Seven people (5 males and 2 females) were interviewed in a group with age ranging from 25-36 and most of the members of the group had Bachelors and Masters in various areas of crop production as early career researchers, with only one Ph.D holder with a rank of Lecturer II who specializes in Mycotoxicology with 7 years research experience. Fungal biology, toxin synthesis, and remediation are the current focus specifically *Aspergillus flavus* attacking groundnuts and maize that produces aflatoxins which are lethal in high doses. Unavailability of hi-tech equipment such as HPLC[3], GCMS[4], and sequencers e.t.c. was the main challenge reported in this organisation and in terms of finance '...it is neither adequate nor timely'. Institution **B** indicated the use of farmer education on conservation practices and environmental health as a means of engagement. They also reported the ratio of extension agent to the farmer was 1:1000 and they considered that the ideal ratio should be 1:30. In terms of research interventions and projects on sustainable dryland agriculture, institution **B** reported they do nothing specifically.

[3] High Performance Liquid Chromatography

[4] Gas Chromatography Mass Spectrometer

6.6.3 Case study of Private Research Organisation (C)

This stakeholder operates from Kano state Nigeria and extending research to dryland areas. This organisation is international in outlook and receives funding from governmental and non-governmental organisations for the purpose of agricultural research for rural development. In '**C**' one person was interviewed who is male, a Principal Scientist with Ph.D. specialising in Systems Agronomy with 25 years' research experience. The institution mainly focusses on cereal and legume cropping systems. Time and workload were the key challenges highlighted by **C** and affirmed funding was 'Not adequate'. This institution relied on farmer training as a means of engagement. In terms of research interventions and projects on sustainable dryland agriculture, **C** reported they had projects intervening on 'fertilizer management, tillage system and crop rotation'. A representative of institution **C** responded that the project they were involved with was at the experimental stage and reported no challenge noticeable now. However, a respondent from **C** reported the need for 'funds' despite not noticing any challenge with the project as reported earlier.

6.6.4 Case study of Agricultural Development Programme (ADP)- (D)

Institution D is an extension provider. Three people (all males) were interviewed in a group aged 46, 55 and 60, they are all extension agents with one just retired. Two of the interviewees hold basic certificate qualifications in General Agriculture and the other Higher National Diploma (HND) in soil conservation with 32, 27 and 18 years' experience in extension respectively. Two hundred farmers are under the extension block spread across different age groups. The ADP is involved in extension around improving farming through communicating improved farming techniques. Lack of time and workload were the key challenges highlighted by **D.** Resource unavailability for extension was also indicated in this organisation. Weekly meetings to communicate information and technology is the main means of engagement in this ADP. This ADP also reported a ratio of 1:100 and suggested 1:20 would be ideal. In terms of research interventions and projects on sustainable dryland agriculture, institution **D** reported 'helping farmers to acquire new improved seeds' and that 'farmers are adopting the new improved seed rather than the old one' and that the challenge faced was rainfall-related issues. When the question was posed to a respondent from **D** on what their opinion was on what can be done to improve the challenge earlier highlighted, the response was;

"Nothing but pray for more rain".

6.6.5 Case study of Agricultural Development Programme- (E)

Institution E is an extension provider. Two people (both male) were interviewed together aged 47 and 57 who are extension agents and hold HND in Forest Technology and National Diploma (ND) in General Agriculture with 21 and 33 years' experience in extension. They both have about 1000 farmers in their extension block of different age ranges. The ADP is involved in extension around improving farming through communicating improved farming techniques. Lack of time, training and workload were the key challenges highlighted by **E** hindering extension. This institution reported that 'training and visits' were the medium of engagement. In terms of extension ratio, **E** reported that the ratio was 1:1000 and suggested a ratio of 1 extension agent: 50 farmers as the appropriate ratio for them. In terms of research interventions and projects on sustainable dryland agriculture, **E** reported 'farmers are advised to adopt new innovations on their farming businesses'. In terms of project implementation, **E** reported that:

"The new farming system is accepted by most of farmers…about 90 % of farmers are on the line of new improved seed varieties".

Based on challenges faced with project implementation, **E** reported 'funds and rainfall' were the challenges faced. And on what they can do to tackle the challenges, institution **E** representative responded that:

> *"My opinion is to encourage methods of water harvesting".*

6.6.6 Research and extension support/ farmer engagement

In terms of challenges faced with research and extension, funding was the common challenge for all the five institutions. Another collective agreement was that there were existing private/Non-Governmental Organisations working side by side the institutions in the research areas with different focus ranging from extending proven technologies (e.g. improved varieties of seeds), and '…detection/identification of toxigenic and atoxigenic Aspergillus *sp* from crop plants' to support women farmers' family health and general food security. A need exists for more collaboration between providers to harmonise services extended and to reduce duplication of effort.

Engagement among research, extension, and farmers around environmental constraints are ongoing in different ways around the study areas. Considering advice given to farmers on enhancing the efficiency of resource use in the drylands in the areas of soil, water, crop, and livestock management, responses were as presented on (Table 6.7) below:

Table 6.7 Farmer advice on resources management in drylands.

	Area			
Institution	**Soil**	**Water**	**Crop**	**Livestock**
A	Nutrient management issues.	Best use efficiency & conservation.	Best bet crops in ideal systems for maximum productivity.	Intensification/integration with crops for enhanced soil fertility management using manures and cropping systems.
B	Conservation through rotation, use of organic manure, conservation tillage/ zero tillage.	Mulching and plough back of plant matter to enhance retention. Alley cropping and cover cropping.	Mixed cropping and selection of adapted varieties.	Integrated farming/organic rearing.
C	Organic and inorganic fertilizer use.	Water harvesting.	Improved varieties of sorghum, millet and groundnut.	Feeding systems and residue management.
D	Soil maintenance, manure application, crop rotation and mixed cropping (millet, sorghum, cowpea).	Farmers to plant early maturing seeds (for sale), and mulching in irrigated fields.	Use of improved seeds.	Nothing (farmers rely on veterinary officials).
E	Manuring, mulching, planting cover crops and mixed cropping.	Improved water harvesting systems. Use of early maturing seed varieties.	Encourage the use of improved varieties.	'Contact inoculators'[5]

[5] When further probed on what they meant by 'contact inoculators', the extension agents said "animal health scientists were the people referred to as 'innoculators'".

6.6.7 Research Projects/interventions on Sustainable Dryland agriculture and their constraints

Interviewees were probed on their involvement in any nature of research or intervention to support sustainable dryland farming and responses are captured in the individual cases above. When the interviewees were asked to rank the most critical areas (from drought, pest & diseases, soil degradation (desertification) and other factors) that need addressing in terms of environmental damage on a 3-scale of '3=most important', '2=moderately important' and '1=least important'; soil degradation was ranked as the most important concern which agrees with Mortimore (2009) that soil fertility is a major constraint to productivity of drylands. Drought was the second most important and pest and diseases were the third important concerns that required addressing.

6.6.8 Training and extension on drylands Good Agricultural (Agronomic) Practices (GAPs)

Interviewees were probed if they extended GAPs to farmers, respondents **A**, **C**, **D** and **E** responded to the affirmative, while **B** did not respond. Figure 6.5 below shows the number of some aspects of GAPs for different production components advocated by research and extension. Although improved seeds, organic fertilizers use, mulching, intercropping and crop rotation were the most popular advocated, not all were utilized for the co-learning activity due to suitability.

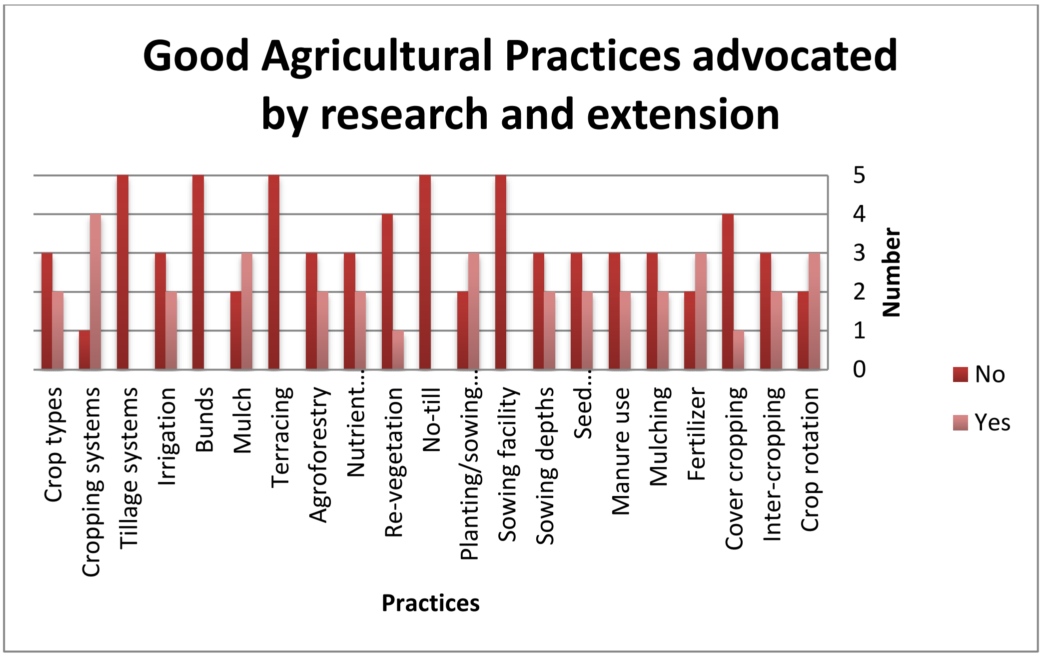


Figure 6.5 Number of GAPs advocated in Dryland areas by Research & Extension.

In response to whether the GAPs advocated were yielding results, institution **A** reported that the ones advocated by them are working, such as 'improved crop varieties with potential for high yields and resistance to major biotic and abiotic constraints'. They also reported that use of compost and manure are vigorously pursued with farmers realizing the benefits on soil fertility improvements. Appropriate sowing date is also determined 'for most crops grown in both rainy and dry seasons.' Micro-dosing of fertilizer with strip cropping of cereals is also advocated with crop rotation that helps with disease management. Institutions **C**, **D,** and **E** reported that the practices were also working but with institution **E** arguing that inorganic fertilizer is too costly.

Interviewees were asked to list conferences/meetings/workshops/discussions on GAPs and dryland farming that they could recall attending recently or in the past and to indicate any additional training needed. Their responses are presented (Table 6.8).

Table 6.8 Conferences/workshops attended and needed on GAPs and Dryland farming.

Institution	Conferences/workshops attended on GAPs	Conferences/workshops attended on Drylands	Further training needed
A	Dryland Systems of CGIAR[6] Consortium.	1st International Conference on Drylands organized by CDA-BUK[7].	On understanding the dynamics of the Dryland Systems & livelihoods of its inhabitants.
B	-Hope phase II workshop. -Monitoring and detection of Afflatoxins (both by ICRISAT[8]) (2014, 2015). -NSPP[9] Conference (2015).	Weed Science Conference (2013).	Water management & crop genetic improvement.
C	No response.	No response.	No response.
D	-Monthly meeting by (KTARDA)[10]. -ICRISAT yearly training.	-As previously mentioned.	-More monthly training if possible.
E	-Innovation platform meetings. -Community/extension meetings. -Workshop on mid/end of season evaluation. -Brownfield day meeting.	-Farmers/extension meetings. -In season training.	-A repeat of the meetings mentioned previously.

When asked to make additional comments on this study, institution **A** requested strengthening of collaboration through some agreements and MoU with relevant stakeholders concerned. Institution **B** representative said crop and livestock adaptation needs to be researched to maintain and increase production focusing on 'environmentally benign technologies which are cost-effective, and community/cooperative agriculture should be encouraged. Institution **B** further reiterated that funding from the public should be supported by the private sector as well

[6] Consultative Group for International Agricultural Research

[7] Centre for dryland Agriculture-Bayero University Kano, Nigeria

[8] International Crop Research Institute for the Semi-Arid Tropics

[9] Nigerian Society for Plant Protection

[10] Katsina State Agricultural and Rural Development Authority

for research and execution. Institution **D** finally added that they have experienced a late onset of rainfall this year (no rain up to end of June 2015) compared to last year when the rain started by the month of May. This was buttressed by one of the interviewees' responses as follows:

> *"…up to now, we have not sown crops… is it global warming?"*

6.7 Discussion

This chapter reports two separate results of stakeholder engagement. First, it is based on a Delphi study that elicited experts' opinion on GAPs and their suitability for soil fertility improvement, rainfall and drought management, degraded land restoration, with preferred methods of training and the potentials for sustainability and GHGs mitigation of those practices. The aim of the Delphi study was to ensure evidence-based GAPs are communicated to farming households as experts were drawn from the academia, research and field practice, hence, their opinions could be relied upon. The results from the two rounds of Delphi were analysed, consensus was reached on the importance of the GAPs selected for soil fertility, drought management, degradation, and pests and diseases management. These were adapted into the training and farmer action plans. The Delphi study also confirmed that some of the GAPs were already practiced in some of those locations making farmers' knowledge very invaluable to the process of innovation uptake. Despite the existing GAPs however, some potential exists for improved application. Although most participants' responses are biased towards their own area of specialty, the wide range of expertise was useful in gathering varied perspectives on dryland management. Delphi technique may not be a definitive method, however, if appropriately utilized, it offers opinions from an array of experts on a specific topic (Hasson *et al.,* 2000). The Delphi technique confirmed the use of GAPs appropriate for ensuring agriculture is practiced in the era of climate change to enhance food security of households while guaranteeing environmental sustainability, and resilience of food system components in drylands of north-western Nigeria specifically. More so, that the subsequent co-learning intervention was more evidence-based and further underpinned the use of the Delphi technique as a decision-support tool (Landeta, 2006). Incorporating experts' views into subsequent rounds help in improving the confidence of the panel members in the Delphi process, thereby increasing the chances of a high rate of consensus. The low level of consensus on whether farmers already use gaps, offers an opportunity to further explore the use of GAPs in the study locations, and thereby offering a justification for the field engagement. Although, a counter explanation for the low consensus could be due to the influence of new panel members introduced at the third round of the Delphi whose responses are likely to reduce the consensus rate. Despite the usefulness of GAPs, the findings indicate that GAPs are not sufficient in themselves, but rather good extension methods are useful for these GAPs to be up taken. Moreover, for better results to be achieved, the findings suggest that a need arises for a holistic approach to the deployment of the GAPs as part of a cropping system as opposed to advocating them as component technologies. This corroborate findings from the research and extension engagement reported in section 6.6.1.

The second results are based on research and extension engagement. Agricultural extension is key to enhancing farmer productivity as it is the most effective means of disseminating research output to farmers. From the results of farmers and extension stakeholder engagement, it is obvious that no consensus exists on the ideal extension ratio for both communities. For effective service delivery, extension agent-farm family ratio is suggested in the literature (Benor and Baxter, 1984) to be 1:250. Current extension ratio in Nigeria is large which could benefit in ratio reduction with a farmer-farmer (lead farmer) extension model proposed in this study (Figure 6.6). It is expected that this model that uses highly performing farmers (those with deeper knowledge of good practices, more literacy, more assets and are highly respected as opinion leaders) to serve as role models will reduce the ‘extension-farmer’ ratio and build capacity in the farming communities when extension agents are not there. In the lead farmer extension model, research into GAPs is expected to pass through the identified lead farmers to the other farmers. Under this model of extension, it is suggested that extension information will be made more accessible to a larger number of farmers within a short duration and using less budget. By so doing, a trained lead farmer can potentially reach 3 to 5 farmers in a cluster thereby reducing the current high extension-farmer ratio.

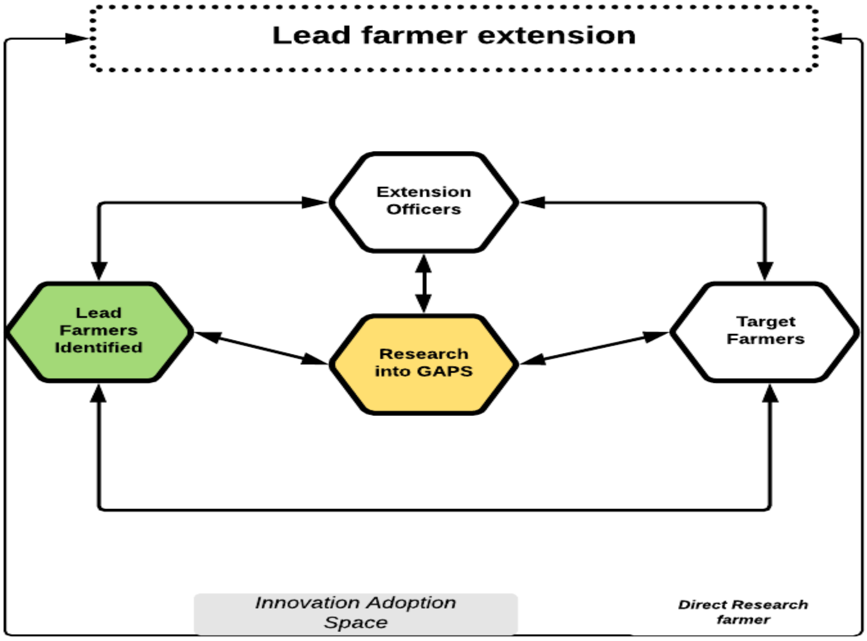


Figure 6.6 Lead farmer extension model.

Although GAPs such as mulching, crop rotation, appropriate nutrient application, intercropping legumes with other crops, cover cropping, revegetation, and agroforestry were similarly advocated by experts and institutions (A-E) as component technologies, there were differences in some practices advocated by experts which the institutions (A-E) did not agree were relevant for the study areas. An example is 'No or minimum tillage'.

Findings from this study show that research is ongoing with interventions for drylands management with few results recorded. However, some researches are not specifically targeted for drylands, hence, the need for the research to be properly targeted and further supported. Public extension in Nigeria is largely supported by donors who often set agendas (top-down) and who only fund for short periods which makes such support unsustainable as the failure of donor support to continue often results in the collapse of the extension structure. This was the case with the ADP model initially funded by the World Bank in the 1980s and 1990s, where withdrawal of such support has led to near extinction of the ADP extension model with resultant effects currently felt in the farming communities. Despite the presence of ongoing research, lack of proper funding was a major constraint reported by all the research stakeholders. Hence, research will benefit from more targeted funding in this area.

The puzzling nature of the current approach to extension has thrown open the question of whether 'pluralism' is the way forward for extension in SSA, to be anchored on participation and demand focused, private supply and augmented with ICT usage (Davis, 2008). Private extension has worked perfectly in the rich developed country context, as it empowers the farmers to decide the nature of information supplied to them and gives them powers to hire and fire the extension agent. However, this approach probes more questions than proffers answers to the existing paradox as poor farmers such as those in Zango and Kofa who are mostly targeted by public extension, are unable to afford payments for private extension thereby losing out in the process. Furthermore, private extension that has a commercial undertone may derive its payments indirectly through the sales of input and technology which smallholders cannot afford. In addition, the inability of these smallholders to gain support to meet their subsistence needs could result in their disinterest in any form of extension even if freely provided (Saliu and Age, 2009). Similarly, Rivera and Alex (2004) corroborated that only governments that have the necessary structure to provide diversified extension support, and to monitor its quality are effective in rural development. Hence, Davis (2008) argues for the stratification of farmers, so that large commercially oriented farmers could be made to purchase services, while subsistent poor farmers continue to receive public extension; this could be tested in the Zango and Kofa context for applicability.

On another note, T & V system of extension was successful in Asia because farming systems practiced there were more homogenous and extension agents and farmers had more capacity. In contrast, while training and visit model of extension are still being practiced in the study communities as indicated by institution **E,** this may not be successful due to the heterogeneous nature of farming systems in Nigeria. Additionally, a gap exists in what the extension agents know and facilitate. Hence, the need for a more practical model of extension that will be meaningful and profitable to all stakeholders.

As earlier stated, the current state of extension in Nigeria is plagued by myriad challenges (e.g. large farmer to extension ratio, poor knowledge of good and resilient practices) which requires a novel approach to the way extension knowledge is developed and shared. What is needed is a continuous professional development (CPD) on improved extension that should form part of a new curriculum on extension that requires the highly skilled and respected farmers to be trained in a new and innovative extension knowledge path. These farmers will serve as lead farmers in a farmer to farmer knowledge exchange, making them serve as frontiers of a novel approach to extension knowledge dissemination that will lead to a more manageable extension to farmer ratio in line with the ratio proposed by the World Bank, and Benor and Baxter (1984). A typical case of the viability of such 'farmer to farmer' knowledge exchange is the case of the "Campesino a Campesino" model thriving in the Central Americas (Rosset and Altieri, 2017). The Campesino movement shares proven good agricultural principles and processes among farmers. By implication, farmers take charge of their development in a horizontal method of knowledge exchange. They control their seed systems, means of production and are actively involved in all stages of the agricultural value chains.

6.8 Chapter summary

Despite the challenges encountered with different models of extension in SSA, this chapter has shown there exist no 'one-size fits all' model that can be implemented generally. However, a realignment of existing models across the globe could be found useful for the SSA context. For example, participatory approaches have been found useful in certain climes with lessons learned to be transferred. Further training of extension staff and farmers alike with appropriate good agricultural practices, group dynamic and marketing skills will help in ensuring sustainable agriculture in the context of food security and environmental conservation; however, the GAPs selected must be appropriate for the conditions and farming systems practiced. A response by one of the extension agents on how they advise on water management 'nothing but to pray for rain' indicates an existing knowledge gap in what extension know and teach. Also, a lead farmer approach to extension would help reduce the extension agent-farmer ratio in the study communities and in the country in general when effectively up-scaled.

The findings from this chapter informed the target GAPs to consider along with training and co-learning of farmers in the study communities; these included GAPs for soil fertility, drought, and degraded land management as indicated in the Delphi study section. The results are reported in the next chapter.

CHAPTER SEVEN

Co-learning and barriers to adoption of GAPs

This chapter resulted in 1 article for publication in preparation as follows:

- Jellason, N.P, Baines. R.N. and Conway, J.S. 'Smallholders and environmental change: Determinants and barriers to adoption of agricultural innovations in north-western Nigerian drylands'

Objectives

The main objective of this chapter is to:

- explore the determinants or barriers to uptake of new practices aimed at enhancing resilience to environmental challenges and food security of two communities in the north-western Nigerian drylands and to add to the existing body of knowledge on farmer engagement.

7.1 Introduction

Climate variability is part of the seasonal experiences of inhabitants of drylands who have evolved adaptation strategies to these uncertain and variable environments (Mortimore and Adams, 2001; Mearns and Norton, 2010). Despite this, there is the argument that collective community knowledge is limited to anticipating weather events that have previously been experienced but not the additional extremes that climate change is predicted to bring (World Bank, 1992; Boko *et al.*, 2007; Adger *et al.*, 2011; Frank and Penrose Buckley, 2012; Danjuma *et al.*, 2014). Any factors that inhibit recognition of change or the adoption of new practices will constitute a barrier to adaptation; this is further impeded by the lack of capacity of local farming communities to respond to the new and emerging impacts of climate change due to lack of access to improved technologies or by poor information and institutional support (Mapfumo *et al.*, 2013). This is true for Nigeria as Huq and Ayers (2007) suggests that it is one of the most vulnerable countries facing climate change with low capacity to adapt due to poverty, lack of technical knowledge and capabilities, poor awareness of climate change and weak institutions (BNRCC, 2008).

Innovations for Sustainable Land Management (SLM) will play a crucial role in managing environmental challenges and while extensive studies on barriers to climate change adaptation exists in developed countries such as Canada, the USA, and Europe (e.g. Jantarasami *et al.*, 2010; Biesbroek *et al.*, 2011; McNeeley, 2012; Matasci *et al.*, 2013), less empirical research has been conducted in the sub-Saharan African context (Sietz *et al.*, 2011; Boyd *et al.*, 2013; Antwi-Agyei *et al.*, 2015). In addition, low investments in such innovations have been recorded in many developing countries (Nkonya *et al.*, 2016) thereby slowing adoption of new practices by smallholders (Shiferaw *et al.*, 2009; Meijer *et al.*, 2015). What limits uptake of adaptation options is not well understood (Antwi-Agyei *et al.*, 2015; Meijer *et al.*, 2015) and needs to be examined and remedied (Thomas and Middleton, 1994; Knowler and Bradshaw, 2007). It is against this backdrop that this chapter explores the barriers to adoption of innovation for climate change adaptation in order to contribute to the debate on the merits of collaborative approaches to innovation uptake. It is anticipated that overcoming the barriers to the adoption of improved soil and water conservation practices, in particular, will enhance the resilience of farmers to climate change, prevent degradation of land in West African drylands and promote food security at the same time (Kpadonou *et al.*, 2017). Adoption of improved science-based practices has been shown to be more successful if participants are fully engaged in the process where they can share their experiences and develop action plans (Mekoya *et al.*, 2008; Mapfumo *et al.*, 2013).

7.2 Participatory Innovation Adoption

Innovation refers to a practice, technical information, an idea or concept perceived by an individual as new (Rogers, 2003; Meijer *et al.*, 2015). Adoption of an innovation is not a straightforward activity as it depends on both the objectives of households and the constraints to adoption (De Haen, 1997). Among the factors that constitute barriers to adoption of innovation include: institutional, socio-economic and cultural barriers (Reed and Stringer, 2016; FAO, 2017). Examples of these factors are financial capital (Burbi *et al.*, 2016); lack of information around policy support, poor land tenure, market failure and infrastructural deficits (Altieri and Nicholls, 2012); appropriateness of the innovation to the end user (Shiferaw *et al.*, 2009; Corbeels *et al.*, 2014); labour requirement and access to external inputs (Giller *et al*., 2009). In addition, other uses of crop residues, for example, animal feeding, can confound decision making for a particular crop (Giller *et al*., 2009; Andersson and D'Souza, 2014).

The process of innovation adoption could also constitute a barrier to adoption. According to Rogers, the choice to adopt is a psychological process that comprises five stages: 'knowledge, persuasion, decision, implementation and confirmation' (Rogers, 2003:170). However, some scholars argue that the process of innovation adoption is not a single universal process (Matthews, 2017). For example, a recent study of indigenous innovation in rural West Africa found that the Hausa farmers adopt innovations through a consensus process where they confer with each other as part of the decision-making process (Matthews, 2017). A critique of Matthews' study is that the consensual process of decision-making by the smallholders is rather primitive and biased to an outsider construction as exemplified in Participatory Rural Appraisals (PRAs) paradigm promoted by Chambers (1994) which favours the most powerful in the communities (Mohan, 2001), hence, making the condition of the poor and less fortunate members of the communities worse. In contrast, the DfID's Sustainable Livelihood Approach (SLA) does focus on the most vulnerable and has the capacity to integrate shocks to the system such as climate change. While agricultural innovation uptake is argued to be dependent on the extrinsic features of the adopter and the external environment during the process of decision-making, new empirical evidence suggests intrinsic determinants of adoption also exist which includes perceptions, attitudes and the knowledge of the potential adopter. Hence, future research on adoption of innovation should consider both determinants concurrently as they are complementary (Meijer *et al.,* 2015).

Past studies on adoption of agricultural innovations erroneously assume innovations to be a perfect fit which can either be adopted or not, and often neglecting the role of the beneficiaries in the process of customisation, development, and demonstration of the innovation (Meijer *et al.,* 2015). Some studies also exists that focused on understanding enablers of adoption and rejection of technologies which are technology and location specific; for example, drip irrigation (Garb and Friedlander, 2014) and the adoption of conservation practices in agriculture (Delgado and Bausch, 2005; Knowler and Bradshaw, 2007; Greiner and Gregg, 2011; Reimer *et al.,* 2013; Ahmad *et al.,* 2014). Since enablers of innovation vary according to specific innovations and place of application, it has been suggested that universal determinants of behavioural change in agriculture do not exist (Knowler and Bradshaw, 2007). Hence, Niles *et al.* (2016) suggested that location-specific case studies are suitable for assessing determinants of adoption for a given situation and to examine the utility of a prevailing theory in diverse settings. The heterogeneous nature of farms in sub-Saharan Africa makes 'place-based' interventions to solve environmental challenges more appropriate, as opposed to a 'one size, fits all' approach. Furthermore, although climate change issues are global in nature, actions to tackle them need to be location specific (Knowler and Bradshaw, 2007; Beddington *et al.*, 2012). Therefore, making technologies 'user-centred', involving the potential users in the process of creating the innovation aids uptake (Mekoya *et al.,* 2008; Wever *et al.,* 2008). In other words, it is not about the adoption of new practices but adaptation which requires an interactive process of learning and co-learning. It is considered that a co-learning approach would promote participation and serve as a means of integrating farmer and scientific knowledge to adapt to climate challenges.

Critics of external innovation facilitation argue that promoters package practices that encourage upscaling without considering ongoing (indigenous) innovations. This is argued to be anathema to the status quo and demonstrates a lack of respect for the intelligence and creativity of local farmers (Mortimore and Adams, 2001; Matthews, 2017). In the place of this approach, Matthews (2017) argued that promoters of external innovations should be willing to recognize and support prevailing institutions as opposed to inducing social change through the introduction of new innovations. Matthews' study shows how the Hausa farmers in Niger are innovating without any form of external support from development organisations. This implies that farmers are innovative enough to manage their challenges as they act rationally. Similarly, indigenous and social organisations are potentially expected to improve the lot of 'weaker community members' (Matthews, 2017). Taking this argument further, researchers may be indifferent about understanding barriers to adoption of external innovation if indigenous innovations are sufficient.

Secondly, while participatory approaches such as the sustainable livelihoods framework are targeted at altering existing power relations to favour the less privileged, the practice may, however, succeed in reinforcing power on the knowledge facilitator (expert) further placing the beneficiary (non-expert) at a disadvantage (Mohan, 2001). Another obvious criticism of the participatory approach is the argument that participation fosters a binary and dichotomous notion of 'insiders-outsiders'; 'expert-local' knowledge and 'beneficiary-facilitator' (Kothari, 2001). Also, participation can act as a means of obscuring 'top-down' approaches by development agencies which can act to 'rubber stamp' and thus validate special interests leading to bias (Mosse, 2001; Scott, 2011); as such, external actors essentially usurp the autonomy of communities (Matthews, 2017). Accordingly, the duality of perspectives oversimplifies complex social dynamics in participatory approaches to development, thereby concealing existing power imbalances (Kothari, 2001). For a review of the criticisms of participatory approaches to development, see Cooke and Kothari (2001).

Contrarily, the above notions may be flawed, as Thaler and Sunstein (2009) argued that humans are emotional and not rational thinkers, do not make the best of choices for themselves as their actions are most often guided by their emotions; hence external facilitation of innovation is not out of place. Moreover, farmers could overlook adaptation to impending environmental and climate change thereby necessitating some form of reminders. Similarly, existing innovation practiced in the highlighted communities could presumably be products of previous external interventions, thus indicating an unwillingness to acknowledge external innovations as in the study by Matthews. Also, findings from Matthews (2017) are based on 16 out of 100 responses which may not be representative enough to generalize the innovativeness (and a reduced need for external facilitation) for Sahelian drylands inhabitants.

On balance, many studies (e.g. Macnaghten and Jacobs, 1997; Reed, 2008; Mapfumo *et al.,* 2013; de Vente *et al.,* 2016) argue that some merit exist in the practice of participatory research for managing socio-ecological systems if the process is properly designed according to a specific context and stakeholder interests. For instance, de Vente *et al.* (2016) argued that for the participatory process to be successful, stakeholders must be adequately represented, with facilitation structured in a professional way to balance power relations among participants; and supply of information and participants' empowerment for decision-making must be ensured in the process. The process also acts to empower the communities with new scientific knowledge that they may have previously lacked. Hence, the use of participatory adoption of innovation in this study.

7.3 Materials and methods

This research was carried out in two communities in the north-western part of Nigeria between March to May 2016 and October to November 2016. Available evidence for such regions shows that the main challenges for these drylands are poor soil fertility, water stress and other crop management related challenges (Kidane *et al.,* 2010). In terms of the two communities, Zango generally experiences lower rainfall, higher temperatures and is drier compared to Kofa. Hence, the target of this co-learning knowledge exchange was to attempt to solve these challenges in the two communities where the farming systems practiced in both communities are similar and include the integration of crops (cowpea, groundnuts, millet, and sorghum) with livestock (sheep, goats, cattle, and poultry).

7.3.1 Selection of good agricultural practices (GAPs)

GAPs were selected based on a previous farmer baseline study and a science-based literature review of the use of GAPs by smallholders in similar drylands. Practices considered include water, land and soil fertility management practices to inform the participatory co-learning process. The usefulness of selected GAPs was verified in a Delphi study where expert consensus was reached on the key GAPs to include (Chapter 6). The list of the GAPs (Table 7.1) was shared with farmers and their scientific underpinnings were further explained through group training and discussions. As part of the process, bio-intensive garden preparation was included as a means of mainstreaming gender and involving women in some form of agriculture through home garden preparation.

Table 7.1 Good practices and scientific evidence underpinning them.

Practice	Benefits	References
Cover crop	-Reduced nutrient leaching[1,2.] -Increased yield[3.]	-FAO (2009)[1] -Tilman *et al.* (2002)[2.] -M'Biandoun *et al.* (2010)[3.]
Mulching	Increased yield by 30% compared to without mulching[5.]	-Kidane *et al.* (2010)[5]
No-till	-30% increase in output[6]. -10-56% yield increase in soybean[7]. -30% yield increase in maize[4].	-Kidane (2005)[6]. In: FAO (2010)[7]. -Knoop *et al.* (2012)[4].
Crop rotation	-Maintains fertility and reduces soil erosion[8]. -Conserves moisture[2].	-Tilman *et al.* (2002)[2.] -Sharma and Singh (2013)[8].
Water harvesting from rooftops/small scale irrigation.	-Yield 24,700 litres from a surface area of 100m^2 with a seasonal rainfall of 260 mm[4].	Knoop *et al.* (2012)[4.].
Bio-intensive garden preparation.	-Builds soil fertility. -Uses small area to produce high yields. -Minimizes water, and organic fertilizer.	Royer-Miller (2010).
Composting	2,449 kg/ha and 5,071 kg/ha was recorded in Machakos and Nyeri respectively[4.]	Knoop *et al.* (2012)[4].
Appropriate fertilizer application.	-Restore soil fertility[2.] -Improved water productivity[9.] -Reduced amount of fertilizer.	Tilman *et al.* (2002)[2.] Wani *et al.* (2009)[9.]

7.3.2 Design of the GAPs co-learning study & participants' selection (lead farmers)

Sixty lead farmers, 30 per community, were selected based on results of the initial baseline study conducted and on recommendations by other participant farmers.

Selected farmers were engaged in GAPs training and co-learning for environmental change adaptation. The study took an approach of the "before-after" intervention method where the perception of participants was recorded before intervention and later evaluated after training to verify whether the intervention has led to change in perception (Soon and Baines, 2012). Training and co-learning methods selected by the participants are presented in Table 7.2. Co-learning in this context refers to the process of identifying and demonstrating good practices facilitated by the researcher in collaboration with the participants using a feedback mechanism. In this process researchers also learn from farmers what works, what does not work and why; this allows any barriers to be explored and remedied.

i. Training and co-learning objectives

The objectives of the training and co-learning were to promote the integration, adoption and subsequent adaption of good practices for rainwater and soil fertility management that were not currently being practiced according to the wider baseline study of 220 farmers (120 in Zango and 100 in Kofa; see Chapter 5). Evidence of successful application of selected practices in similar regions was shared and discussed in order to validate the benefits of such practices. As a result, each farmer developed, with assistance, their own action plan (Plate 7.2) (Mapfumo *et al.,* 2013).

ii. Selection of training options and ranking of most important focus of training

Sub-optimal consequences from the adoption of innovations could result from lack of participation of end-users in the process of designing the innovations (Wever *et al.,* 2008). Hence, participants were involved in focus group discussions (FGDs) to select the most appropriate GAPs and the best form of learning suitable to their conditions (Table 7.2).

Table 7.2 Ranking best training options preferred for the co-learning exercise.

Community	Training
Zango	Training and field demonstration (1st), farmer to farmer training (2nd), training and action plan (3rd).
Kofa	Farmer to farmer training (1st), training and field demonstration (2nd), innovation platforms (3rd).

iii. Practical training and field demonstration

Based on the preferred GAPs and training options selected by the participants in the two communities, field demonstration, training and action planning were all implemented in the co-learning process. The farmer-co-learning materials were developed based on feedback from the initial Delphi study aimed at seeking expert opinions on best GAPs for resilience enhancement for dryland farmers (Chapter 6). The selections were based on the usefulness of practice for rainwater and soil fertility management in sub-Saharan African drylands (Table 7.1). Pictorial (posters) co-learning materials were developed for each of the practices selected with 'shout outs' in the local language (Hausa) for easy understanding. This is consistent with Soon and Baines (2012) who asserted that the use of visuals and demonstrations for training produces a relaxed atmosphere thereby enhancing learning. These can be said to be part of a participatory mapping process. As examples of this training, some of the techniques used were: Ropes, tapes, used in measuring correct rows and basin spacing and hoes for digging planting holes for minimum tillage. Additional materials included bottle tops for marking planting distances along ropes and durable wooden pegs for holding the ropes together. Once the materials were all set, practices were then demonstrated (plates 7.1 and 7.3).

Minimum tillage demonstration with 25cm x 75cm seed spacing and point application of nutrient

Plate 7.1

Filled farmer action plan

Plate 7.2

Rooftop water harvesting structures

Plate 7.3

Plate 7.4

7.3.3 Evaluation of training and co-learning

Questionnaires were administered to these farmers prior to training to understand their levels of satisfaction, confidence levels about solving water and poor soil fertility related challenges, current yields and cost of carrying out farm practices (Appendix 5h). The same questions were then administered to the same farmers six months after the co-learning exercise at the post-harvest period to explore the impacts of the co-learning on farm operations. A separate questionnaire was developed to appraise the level of adoption, drivers, and barriers to adoption of the co-learning practices (Appendix 5i).

a. Pre- and post-training questionnaires

Data were collected using both focus group discussion (for selection of co-learning methods and vulnerability analysis-reported in Chapter 8) and semi-structured questionnaires developed for this study which consisted of two sections, demographics and general information on current farming situations and practices. Demographic questions included age, gender, educational level and name for easy tracking of participants at the post-learning evaluation stage (Table 7.3). The general information section consisted of twenty questions on satisfaction with current practices, confidence in the ability to solve water and poor fertility challenges, pre-learning practices that need changing, type and amount of input used, labour time and tillage cost, planting, weeding and harvesting. The questionnaires were then piloted with three African postgraduate students in the researchers' institution and poorly framed questions were corrected. Twenty-one farmers in Kofa and 24 in Zango were tracked at the post-harvest adoption appraisal stage; the attrition rates recorded were due to reasons of sickness, inability to locate respondents and some travelling out of research locations.

7.3.4 Data analysis

Data were analysed using IBM SPSS, version 23. Median and percentages were calculated and a non-parametric test (Wilcoxon Signed Rank Test) was carried out to compare results before and after training; this technique was employed due to the small sample size and lack of stringent requirements of normality with parametric techniques (Pallant, 2013).

7.4 Results

Participants selected from the two communities for the training and co-learning represented different age categories, gender and educational levels (Table 7.3).

Table 7.3 Demographics of training and co-learning participants.

Demographic item	Zango-n=30 (%)	Kofa-n=30 (%)
Gender		
Male	21 (70.0)	23 (76.7)
Female	9 (30.0)	7 (23.3)
Age		
18-20	11 (36.7)	16 (53.3)
21-40	4 (13.3)	4 (13.3)
41 & above	15 (50.0)	10 (33.3)
Education		
No education	13 (43.3)	12 (40.0)
Primary	1 (3.3)	9 (30.0)
Secondary	5 (16.7)	4 (13.3)
Tertiary	11 (36.7)	5 (16.7)

7.4.1 Training outcomes

This research clearly addresses the many arguments about external support for innovation adoption in the literature; only participants captured in the pre- and post-training and co-learning program were used for this analysis (Appendix 9a & b). The test revealed a statistically significant difference in 'Solving Environmental Problems' affecting farming following participation in the co-learning program, for Kofa $z = -2.27$, $p < 0.05$, with a medium effect size ($r = 0.35$); and for Zango $z = -3.70$, $p < 0.05$, with a large effect size ($r = 0.52$). The median score on the 'Solving Environmental Problem Scale' for Kofa was constant pre- and post-co-learning ($Md = 4$). Whereas the median score for Zango increased from pre-co-learning ($Md = 3$) to post- co-learning ($Md = 5$). This implies that the training and co-learning had positive impacts in increasing the confidence levels of farming households to solve their environmental challenges compared to before training in Zango while in Kofa there were no impacts recorded. The difference between the two communities could be due to the adverse environmental condition experienced in Zango (driest community) compared to Kofa that has a less adverse environmental condition. In Zango community, rainfall is lower, temperature very high compared to Kofa community with relatively higher rainfall regime and moderate temperature that favours more crop growth and establishment. Although there were differences between the two communities, it was considered that participatory training should be encouraged as a means of managing socioecological systems and to compare results.

In terms of 'Yield differences' and 'Confidence about Solving Drought challenges', Kofa participants, showed significant differences pre- and post-training for crop yield differences, $z = -3.40$, $p < 0.05$, with a large effect size (0.52) compared to Zango; Median score for crop yield increased from pre-co-learning ($Md = 4$) to post- co-learning ($Md = 5$). This connotes that training was useful in improving crop yield of participants especially for Kofa, compared to those without training, thereby making training a worthwhile objective to be pursued. The spatial differences in the benefit of training may be connected to the relatively more access to extension information through television in Kofa compared to Zango (Section 5.5.4).

For 'confidence about solving drought challenges', $z = -3.80$, $p < 0.05$, with a large effect size (0.59). Median score for 'Confidence to Solve Drought Challenges' increased from pre- co-learning ($Md = 2$) to post- co-learning ($Md = 4$). This signifies that training was useful in improving the ability of participants to tackle future drought challenges. Other practices that showed significant differences after the co-learning program in the two communities are marked with asterisks (*) in Table 7.4. The implication of this result is that training and co-learning were more effective in increasing yield and the confidence to solve drought challenges in Kofa compared to Zango. Hence, policy formulation for productivity and drought management should focus on knowledge promotion through farmer training as these have been proven to yield positive results.

Table 7.4 Wilcoxon Signed Rank Test Kofa (n=21) and Zango (n=25). r=z/√n. where n= (cases x 2).

		Kofa			**Zango**		
S/no	**Item**	**Z**	**r**	**Sig. (2-tailed)**	**Z**	**r**	**Sig. (2-tailed)**
1.	Happy with current practices	-1.51	0.23	0.132	-0.56	0.08	0.57
2.	Happy with current yield	-3.40	0.52	**0.001***	-0.09	0.01	0.928
3.	Confident you can solve environmental problem	-2.27	0.35	**0.023***	-3.70	0.52	**0.000***
4.	Do you need training to support your farming	-1.29	0.20	0.197	-0.06	0.01	0.953
5.	Do you feel confident to solve water and drought challenges	-3.80	0.59	**0.000***	-1.68	0.24	0.094
6.	Do you feel confident to solve soil fertility challenges	-0.73	0.11	0.463	-0.48	0.07	0.632
7.	Do you think women have a role to play in food security	-1.86	0.29	0.063	-1.18	0.17	0.239
8.	Litres of herbicides used in total	-1.93	0.30	0.053	-0.54	0.08	0.589
9.	Bags of fertilizers used	-2.07	0.32	**0.039***	-2.01	0.28	**0.044***
10.	Bags of produce harvested	-2.12	0.33	**0.034***	-1.07	0.15	0.285
11.	Cost of labour for tillage	-1.93	0.30	0.053	-0.13	0.02	0.896
12.	Cost of labour for weeding	-2.57	0.40	**0.010***	-0.44	0.06	0.660
13.	Cost of labour for harvesting	-1.68	0.26	0.092	-1.89	0.27	0.059
14.	Time spent on clearing	-0.84	0.13	0.403	-0.24	0.03	0.813

15.	Time spent on tillage	-0.04	0.01	0.971	-2.31	0.33	**0.021***
16.	Time spent on planting	-0.46	0.07	0.646	-0.73	0.10	0.467
17.	Time spent on weeding	-0.35	0.05	0.723	-0.78	0.11	0.438
18.	Time spent on harvesting	-3.15	0.49	**0.002***	-3.62	0.51	**0.000***

*significant difference ≤0.05.

7.4.2 Farmer engagement on determinants of adoption and barriers to non-adoption

Adoption of innovation has been found by numerous studies to be influenced by several factors. In this study, some practices were fully adopted while others were partially adopted and in few cases, practices were not adopted at all. Results from the post-co-learning appraisal show very different levels of adoption of the various practices (Figures 7.1 and 7.2). Improved seed varieties were highly valued and adopted in the two communities (a few improved seeds was given to each of the participants as an appreciation for participating in the research which may have biased their opinions on this). Like this study, the role of incentives in dramatically increasing adoption of innovations has been reported in the literature (e.g. Rogers, 2003). West African farmers have been found to always expect something in the form of fertilizers, improved seeds or any support in return for agreeing to participate in studies of this nature. Adoption of appropriate fertilizer application practices was also high in the two communities; the participants explained at the appraisal survey that this practice helped in reducing the total amount of fertilizer used and the cost of fertilizers which constitute a high-cost input to farming.

Composting was more highly rated in Zango than Kofa, as participants in Zango reported prohibitive cost of inorganic fertilizers, as fertiliser support was not offered in this study. Other practices highly adopted in Zango were: 'no burning of crop residue', 'crop rotation' and 'mulching and cover cropping'. Crop rotations, no-till, and straw mulching have increasingly become important methods of maintaining soil productivity and structure (Knowler and Bradshaw, 2007). Comments on the drivers for the adoption of 'no burning of crop residues' included: 'because it was well understood', 'to control soil erosion', 'source of livestock feed', 'to protect soil cover', and participants 'not used to burning crop residue'. For mulching, reasons for adoption included: 'it suppresses weed', 'enhances fertility', 'based on advice given from training' and 'to conserve water'. For Kofa community, mulching was highly adopted to retain residues for water retention in furrows based on advice given, to reduce wind effects, and for fertility enhancement. On the other hand, 'no burning of residue' was highly adopted because crop residue is used as a source of livestock feed and for water retention in furrows to avoid crops drying up. In addition, participants not being used to burning residues was given as another reason. For crop rotation reasons included: to identify the most suitable site and because it promotes yield increases.

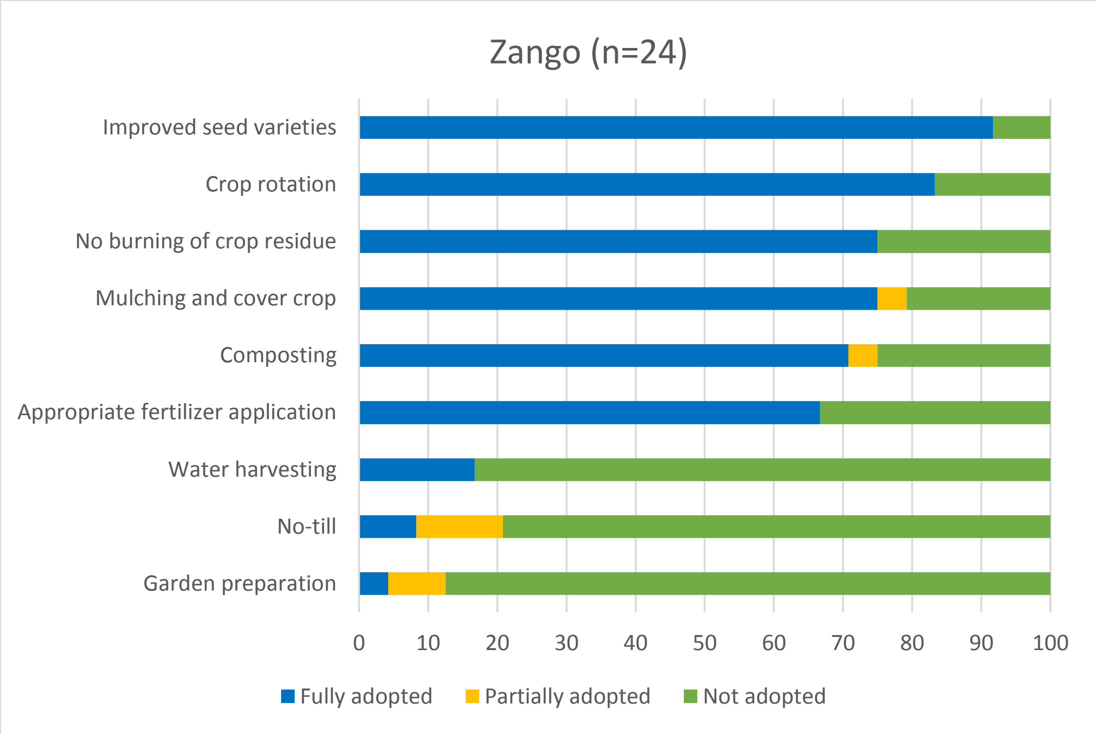


Figure 7.1 Adoption rates of GAPs introduced for co-learning in Zango.

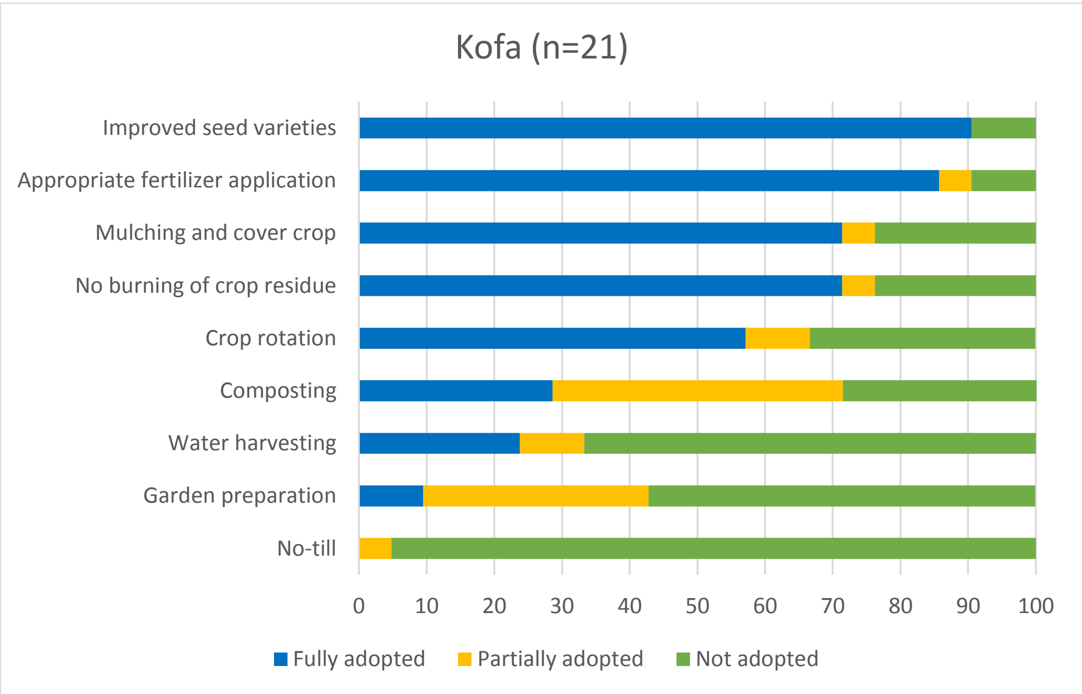


Figure 7.2 Adoption rates of GAPs introduced for co-learning in Kofa.

7.5 Barriers to innovation uptake

Several barriers were responsible for poor uptake of some of the practices in the two communities with the percentage of non-adoption highlighted. To understand these barriers, households were probed on what limits their uptake of innovation for resilience enhancement in their communities. Practices with a non-adoption rate above 50 % for the two communities was set as a benchmark in this study and reasons for non-adoption are presented in Tables 7.5 and 7.6. Coincidentally, similar practices were not adopted in the two communities, albeit, at different rates.

Table 7.5 Practices with the highest non-adoption and reasons Kofa (n=21).

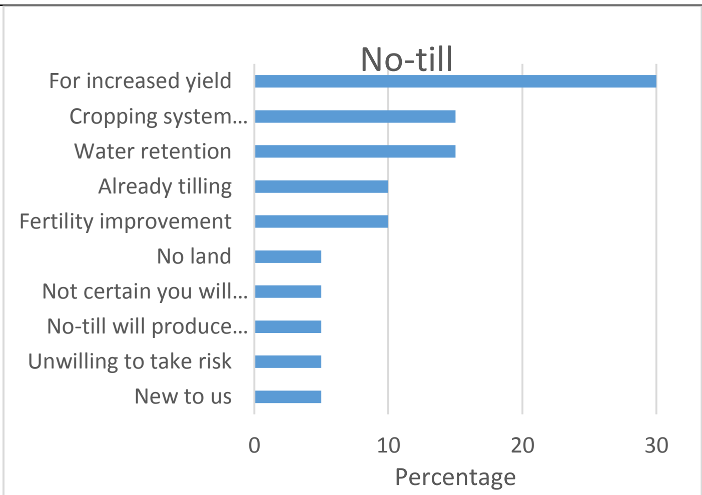
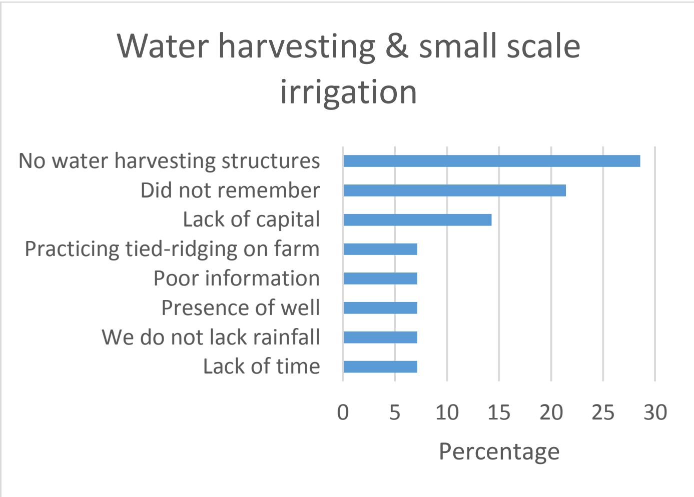
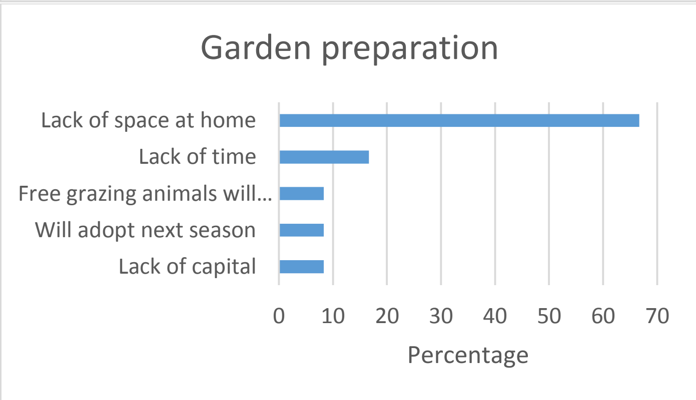
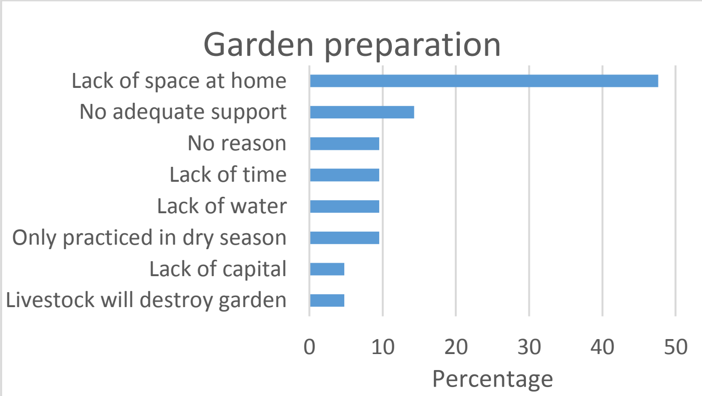
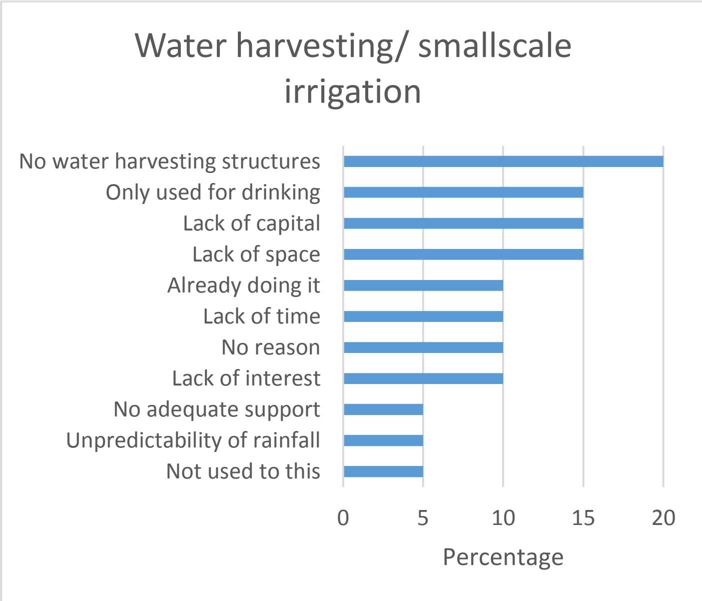
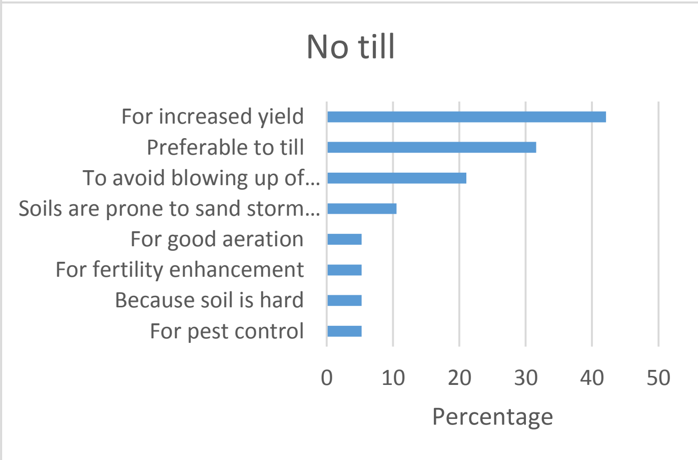
Practice	Reason for non-adoption	Percentage of farmers
No-till		95
Water harvesting/ Small-scale irrigation.		67
Garden preparation.		57

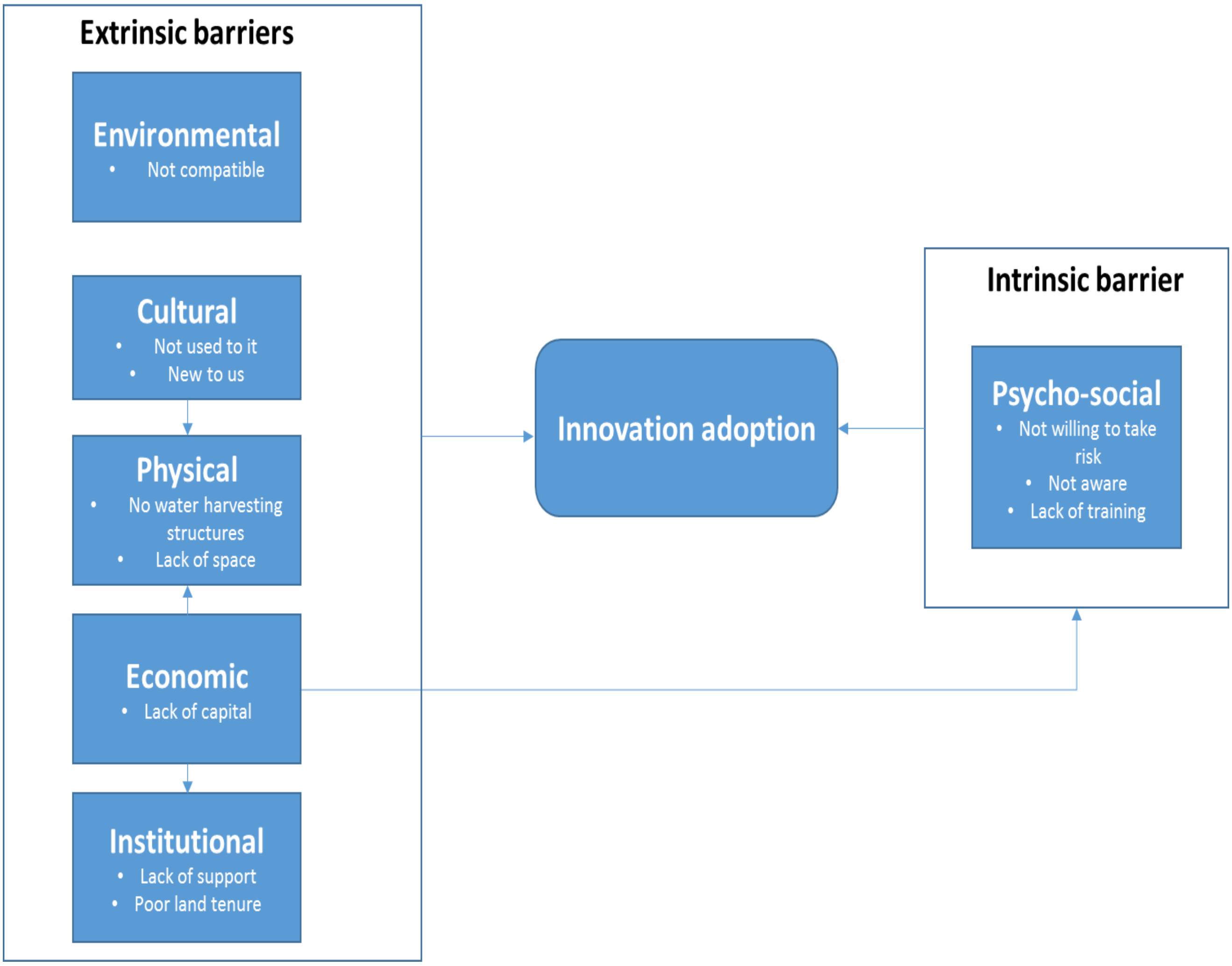
Table 7.6 Practices with the highest non-adoption and reasons Zango (n=24).

Practice	Reason for non-adoption	Percentage of farmers
Garden preparation		88
Water harvesting/small-scale irrigation		83
No-till		79

7.6 Discussion

The results from this study corroborate other studies that point to a range of barriers to adaptation for climate change in sub-Saharan Africa (e.g. Mapfumo *et al.,* 2013; Tambo and Abdoulaye, 2013; Antwi-Agyei *et al.,* 2015). The findings are also in line with de Vente *et al.* (2016) who reported that participatory processes are useful for managing socio-ecological systems if properly designed and Meijer *et al.* (2015) who argued that extrinsic and intrinsic barriers exist which are complimentary as indicated (Figure 7.3). High adoption of 'no burning of crop residue' is not surprising as leaving crop residue in the field has previously been reported as an essential sustainable soil and crop management practice, and a key element of conservation agriculture (Giller *et al*., 2009). However, the practice is limited in conservation agriculture due to alternative uses of crop residue (Giller *et al.,* 2009; Corbeels *et al.,* 2014) – such as for animal feed.

In terms of barriers, some findings are consistent with Mekoya *et al.* (2008) who suggested that farmers' ability to understand and adapt a technology to their local context facilitates long-term adoption. Training has also been reported as an important determinant of adoption of soil and water conservation technologies in West African Sahel (Kpadonou *et al.,* 2017), which also agrees with the findings from this study, where practices such as mulching were adopted based on the training and advice given.



Note: Direction of the arrow shows the source of influence. Developed with ideas from Meijer *et al.* (2015).

Figure 7.3 A conceptual framework showing interactions among extrinsic, and between extrinsic and intrinsic barriers to innovation adoption in Zango and Kofa.

The barriers identified in this study are discussed under the following sub-headings: cultural, economic, environmental, psychosocial, physical and institutional barriers.

7.6.1 Cultural barriers

Cultural barriers recorded include: 'not used to this' and 'new to us'. These barriers have implications for Sustainable Land Management (SLM) as previously reported (Reed and Stringer, 2016). This is because some farmers are mostly unwilling to change their seasoned traditional practices (Long *et al.,* 2015). This agrees with findings in this study, where participants in Zango opined that some practices such as 'No-till' were entirely new to them and that adopting such practice will expose them to risks and uncertainties. The soils in Zango community are hard due to poor availability of rainfall and therefore tilling helps in improving rainfall infiltration. This resonates with Corbeels *et al.* (2014) where farmers argued that they carried out tillage to improve water infiltration in the soil. Findings from this study further revealed that some farmers did not uptake new methods because they were accustomed to their old methods. Compatibility of innovation in a location is a critical consideration for promoting innovation to achieve a high rate of uptake as reported by previous researchers (Rogers, 2003). No-tillage by implication is not compatible with the dry vegetation of Zango. Hence, it is reasonable for the farmers to reject the practice.

7.6.2 Economic barriers

Respondents reported lack of capital as a barrier to the uptake of practices including water harvesting and garden preparation in both communities. This portrays lack of capacity and a serious setback to the promotion of resilience in the two communities thereby necessitating some sort of external support. This finding is in conformity with Adesina and Chianu (2002) who argued that economic factors were among the key determinants of adoption of alley farming innovation in Nigeria. Reed and Stringer (2016) reported that options for adaptation operate within the confines of capital assets accessible to individuals, households or communities. Hence, capital is a key priority for resilience promotion as Burbi *et al.* (2013) reinforced this assertion arguing that economic barriers will potentially limit GAPs implementation for smallholder agriculture. Similarly, lack of credit has previously been found by other researchers as a key constraint to adoption of innovation for adaptation to climate change in the Savanna zone of Nigeria (Tambo and Abdoulaye, 2013) and drylands of northern Ghana (Antwi-Agyei *et al.,* 2015). Adoption of new technology requires financial capital investment, particularly if new equipment is a prerequisite - countries of the developed world offer assistance to farmers for such investments in form of tax exemptions on machinery, direct subsidy and cost sharing (Knowler and Bradshaw, 2007), as resource limitations impact service delivery in most institutions. It will be interesting to see how policy will fashion the best form of assistance in a developing country context to avoid farmers returning to old practices when support is withdrawn.

7.6.3 Environmental barriers

From this study, it could be seen that 'No-till' was not appropriate for Zango community due to incessant sand and dust storms in the area, so it was noted and not promoted. Negative impacts of innovation on the environment is a major constraint to adoption of such an innovation (Fuglie and Kascak, 2001) and thus acts to limit targeted farmers from adopting the innovation.

7.6.4 Psycho-social barriers

Participants in this study reported non-adoption of some practices such as 'rainwater harvesting' and 'no or minimum tillage' due to an unwillingness to take risks and lack of familiarity with the practices. This is not surprising as farmers are mostly risk-averse to untested practices. This is in line with Hardaker *et al.* (2004) who argued that adoption of an untested 'improved' technology may possibly expose the farmer to risk, this is true when it involves high capital investment. Similarly, findings from this study agree with Matthews (2017) who argues that farmers are always reluctant to try new things they have never tested. In contrast to this assertion, the participants in this study were engaged on the benefits of the introduced technologies followed by field demonstrations to promote long-term adoption. Although the field demonstrations did not lead to long-term trials due to the time limit of the study-being part of a Ph.D, it was sufficient to demonstrate the benefits of the practices. Investing in social capital of farmers through training will aid adoption of innovation based on skills gap identified in the study communities which should be a target for policy.

7.6.5 Physical barriers

Lack of water harvesting structures was a key barrier to the adoption of water harvesting practices in the two communities. However, a female farmer in Kofa (Plate 7.3) in consultation with her husband took out a loan from a local money lender and invested in a water harvesting tank to produce vegetables in commercial quantities with the hope of repaying the loan through the sales of her produce, which she achieved - a lesson useful for other financially constrained farmers to consider. This limitation aligns with the lack of capital or economic barriers to innovation uptake as lack of capital hinders the physical acquisition of these structures. Lack of space to adopt some of the practices such as vegetable gardening was also a key constraint to adoption in the two study communities as only the families living on the outskirts of the town were reported to be practicing home gardens due to space availability. This implies that the goal of mainstreaming gender through women participation in home garden preparation for household food security is at risk of lack of space.

7.6.6 Institutional barriers

As reported in this study, poor institutional support has been found in other studies (Mapfumo *et al.*, 2013) amongst other factors to limit the capability of local farmers to adapt to new impacts of climate change in Wenchi district of Ghana-West Africa and Makoni in Zimbabwe, thereby increasing vulnerability to climate change. This is in line with findings in this study that show lack of support as a barrier to adoption of water harvesting and gardening in Zango community, while poor land tenure arrangement was a barrier to adoption of 'No-till' according to some participants in Kofa community. Poor land tenure policy was previously reported as a great barrier to farmers' decisions on technology adoption (Meijer *et al.*, 2015). Antwi-Agyei *et al.* (2015) also suggested that extension officers who serve as links between research stations and farmers to disseminate climate information are often overwhelmed by the number of households or communities they must serve. Though lack of market has been reported as a barrier for non-adoption of agricultural innovation in Africa (Corbeels *et al.*, 2014; Antwi-Agyei *et al.*, 2015), it is not stated in this study. This is presumably because of the less involvement of the participating households in commercial agriculture. Hence, overcoming these barriers through public investment will improve the adoption of these innovations and make farming a viable venture in those communities.

7.7 Chapter summary

Previous studies have mostly found capital, poor knowledge, and awareness as the key barriers to adoption of innovation in sub-Saharan Africa. However, this study reports cultural and physical barriers such as ‘not used to it’, lack of space and water harvesting structures as the dominant barriers to adoption of innovation. Findings reveal that barriers do not operate independently, but rather are reinforced or weakened by each other as indicated by the interactions in the conceptual framework (Figure 7.3). Because farmers have a poor understanding of the science of climate change, participatory approach to learning and awareness creation is required to increase adoption of practices. Poor access to land for garden preparation by women at home reduced the likelihood of preparing a garden by most women in both communities. However, farming families that live outside of towns were more likely to prepare a garden due to land availability. These findings have important policy implications as most women in these communities do not engage in agriculture due to religious and cultural reasons and the backyard garden preparation was chosen to mainstream gender and improve women participation in agriculture. Results of the pre- and post-co-learning revealed that the co-learning exercise improved some key variables such as confidence to manage environmental challenges in the two communities. Interestingly, there was no significant difference in some practices after the training although this was not unexpected as participating farming households indicated lack of interest in some of the practices displayed as they were averse to risks of adopting a new practice. It is hoped that the findings from this work will contribute to a deeper understanding of processes to innovation uptake for resilience enhancement.

These findings form the basis for further detailed research on the role of gender, age and education as determinants of adoption. Further research should consider long-term post-adoption appraisal as the current study was based on six months post-adoption, which may not be very informative due to the time limit.

CHAPTER EIGHT

Vulnerability and socioecological resilience

This chapter resulted in a paper sent for publication as follows:

- Jellason, N.P, Baines. R.N and Conway, J.S. (forthcoming) 'A qualitative approach to assessing environmental challenges and climate change vulnerability: Perspectives from north-western Nigerian Drylands' Climate Risk Management (Newly submitted)

In this chapter vulnerability through a socio-ecological system's lens in an agricultural context is considered (Adger, 2000; Walker *et al.,* 2004; Adger, 2006). Socio-ecological systems (SES) refer to the mutual interaction between 'societal (human) and ecological (biophysical) subsystems' (Gallopín, 2006). Furthermore, the chapter aims to address the following objectives; to:

- explore human vulnerability to climate variations in two dryland communities in North-Western Nigeria by Focus Group Discussions (FGDs) - a qualitative approach to vulnerability assessment given the difficulty of quantifying vulnerability without obscuring its complexity and reducing its impact (Alwang *et al.,* 2001);
- identify transitioning pathways from vulnerability to resilience.

8.1 Background and context

As the world struggles to feed its increasing population amidst challenges of poverty, water shortages, credit and energy crises (Hanjra and Qureshi, 2010), climate change, in particular, imposes further constraints with diverse implications for agriculture and food security (Abiodun *et al.,* 2011). Such climatic challenges will vary geographically with more extreme and longer drought experienced in regions of southern Europe and West Africa (IPCC, 2012); with heat waves causing mortality in Europe for example (Reed and Stringer, 2016). Whilst such variations potentially impact vulnerability, and undermine the resilience of agricultural systems (Gitz and Meybeck, 2012), climatic evidence suggests that regions such as north-western Australia and central North America, in sharp contrast, have more recently experienced shorter and less frequent droughts and therefore, beneficial climate impacts (IPCC, 2012).

The IPCC (2012) reports that climate change in Africa threatens to exacerbate vulnerability concerns due to poor adaptive capacity and endemic poverty, with resultant adverse outcomes expected to include heightened food insecurity and increased malnutrition. Given that resilience assessment is context dependent (Carpenter *et al.*, 2001), the foregoing buttresses the assertion that a system or community having less adaptive capacity and that is sensitive and exposed to the vagaries of the climate and its harsh impacts, is likely to be more susceptible while those with more adaptive capacity are more likely to be resilient (Smit and Wandel, 2006). Climate vulnerabilities and risks in drylands and other related tropical ecosystems located in Africa have been less considered in the published literature compared to the threats to temperate regions, indigenous communities and small island nations (Liverman, 2008). Furthermore, many previous studies on climate impacts have focused on chemical, biological and physical effects; while the assessment of impacts on humans requires exploration into the ways in which societies may respond through different coping strategies, resilience promoting practices and adaptation in the long-run (Adger, 2001; Watson, 2014).

In Nigeria, agriculture is mostly practiced in the rainy season, which lasts about four months in the northernmost part of the country. More recently, the frequency of violent storms at the beginning of seasons led to continuous soil erosion, crop damage and hence distortion of the natural ecosystem's resilience (Ola-Adams and Okali, 2008). This leads us to ask what impact these changes in weather patterns are having on the vulnerability of dryland communities and whether the inhabitants are evolving any strategies for increased resilience?

8.2 Vulnerability and resilience framework

The foremost research paradigms on adaptation to environmental challenges centre on the role of social actors in managing environmental shocks and stresses to minimise vulnerability. Resilience viewpoints have gradually crept into discourses on understanding of socio-ecological system dynamics (Folke, 2006), prompting interests among government departments, environmental lobby groups, consultancies and think tanks on how to build the resilience of both organizations and places (MacKinnon and Derickson, 2012). Resilience to drought or dry spells is important for water security and in this context resilience thinking shifts attention from optimizing growth in terms of yield and efficiency to the capability to adapt, recover, develop, and remain flexible (Falkenmark and Rockström, 2008).

The resilience concept was originally used in the field of ecology (Holling, 1973); however, since then the concept has received wide application in interdisciplinary fields that have explored the nexus between nature and people (Carpenter *et al.,* 2001; Folke *et al.,* 2010; Standish *et al.,* 2014). The resilience approach to adaptation is argued to be systems based, more vibrant, and it perceives adaptive capacity as a principal characteristic of a robust social-ecological system (Carpenter *et al.*, 2001; Walker *et al.*, 2002; Smit and Wandel, 2006; Nelson *et al.,* 2007). Systems, in one way or the other, are affected by the same shocks based on their vulnerability but they can recover easily based on their resilience function (Gitz and Meybeck, 2012).

Despite its wide application by environmental managers and policy makers, resilience remains an imprecise concept that is varied and difficult to measure (Brand and Jax, 2007; Myers-Smith *et al.*, 2012; Standish *et al.*, 2014; Freshwater, 2015). This assertion is supported by MacKinnon and Derickson (2012) who suggested that resilience as a concept is problematic in its approach as it places the burden of managing risks such as climate change on local communities and actors; hence, offering an alternative concept of 'resourcefulness' as a construct that challenges the supremacy of 'neoliberal capitalism' (MacKinnon and Derickson, 2012:267) or put more simply, top-down development. This is why resilience approaches are more capable of capturing 'multiple arenas of governance' (Walker and Cooper, 2011).

Furthermore, MacKinnon and Derickson (2012) argued that the proposed 'resourcefulness' elements consider the unequal distribution of resources across communities giving room for possible self-empowerment of communities using local skills and knowledge. However, limits exist to how far the concept of resourcefulness can be taken under a climate change scenario, as current climate change events are surpassing collective local knowledge and experiences of rural communities, hence requiring the input of external knowledge and support to extend community knowing of their evolving environment – this is the proposition for resilience thinking. Other critics of the resilience concept (Béné *et al.,* 2012) assert that resilience does not capture poverty reduction as one of its core objectives based on its emphasis on 'systems' thereby arguing that it is an 'anti-poor' concept. This was further emphasised by some social researchers (e.g. Leach, 2008; Davidson, 2010) who argued that resilience is limited as a concept in inappropriately acknowledging the role of 'power' and 'agency' of people, and in negotiating their choices (Béné *et al.*, 2012). Agency in this context according to Lister (2004: 125) connotes the role of individuals as: 'autonomous, purposive and creative actors, capable of a degree of choice'.

The above assertions were disputed by Reed and Stringer (2016) who asserted that vulnerability assessment in the context of desertification, land degradation and drought (DLDD) pays special care to the needs of the poor in the course of solutions development for resilience building. The chronic poor, according to Reed and Stringer (2016), make up 16% of the 2.5 billion global drylands populations, they rely on the natural resources for their livelihood, they lack assets and the capacity to adapt to climatic perturbations that affect their livelihood and this makes them vulnerable to degradation and climate impacts. Whilst vulnerability analysis could be either quantitative or qualitative and applicable to any scale from international to local (Reed and Stringer, 2016), resilience is built on the premise that a system in its natural state is dynamic rather than in a state of equilibrium (Holling, 1973). Thus, the capacity of the system to persist and sustain function amid disturbance is an appropriate measure of resilience (Gunderson and Holling, 2001) as opposed to viewing the system as a 'stable' entity that strives to avoid disturbance to achieve resilience as favoured by some scholars such as Pimm (1984).

Like resilience, vulnerability has also been applied in multidisciplinary research paradigms (Smit and Wandel, 2006) and also considered context specific with no generally accepted meaning (Gallopín, 2006; Reed and Stringer, 2016). Qualitative vulnerability assessment considers systems' exposure to trepidation and traits that 'confer adaptive capacity and sensitivity to disturbance' (Mumby *et al.,* 2014). For most natural threats, the susceptibility of human populations is determined by their location, natural resources use and resource availability to adapt (Adger, 2006). The analysis of vulnerability aims to ascertain the most susceptible populations and decide actions for adaptation to reduce susceptibility to perturbations while promoting sustainability (Nelson *et al.,* 2007; Ribot, 2010).

The literature on the cause of land degradation points to both human and natural drivers based on land use change and climate change (D'Odorico *et al.,* 2013). Reed and Stringer (2016) argue that land degradation is caused by human activities but worsened by natural climatic events which threaten long-term economic and biological resilience and the capacity to adapt by the populations and ecosystems they are dependent on. Other literature argue on the contrary suggesting that land degradation is a result of natural phenomena (UNCCD, 1992) exacerbated by human activities (Safriel and Adeel, 2005) or an interplay of both factors (D'Odorico *et al.,* 2013). The literature on vulnerability and resilience is argued to be a controversial one, however, each model has a distinct and complementary function (Mumby *et al.,* 2014). It is against this backdrop that this study adopts the vulnerability framework advocated by the Intergovernmental Panel on Climate Change (IPCC) and promoted by Reed and Stringer (2016) to explore the vulnerability or resilience condition of households in the study communities. The study explores the levels of exposure to environmental challenges and climate change, sensitivity to the exposure and to what extent the ability to maintain current function is affected; it also explores whether adaptive capacity exists to tackle the exposure or not. Moreover, we explore whether a change of focus is necessary from efficiency and production goals of farming to learning and adaptability in line with current resilience thinking (Darnhofer *et al.,* 2010).

8.3 Materials and methods

This study was undertaken between 22nd March and 22nd May 2016 in two communities - Zango and Kofa in north-western Nigeria as a follow-up to an initial baseline livelihoods study (Section 5.5.2) carried out in June 2015.

Focus Group Discussions (FGD) were employed for data collection. Specific themes were explored in-depth to get a group view of vulnerability in the communities and the facilitator was not too intrusive while moderating (Bryman, 2012). Despite its time consuming and expensive to organise nature (Denscombe, 2014), it was used in seeking divergent views and not consensus (Crang and Cook, 1995; Finch *et al.,* 2014).

The FGDs was explored to get a shared creation of meaning which is regarded as '*more naturalistic*' and also helps researchers to develop an understanding of why people feel the way they feel (Bryman, 2012; Crang and Cook, 1995). Also, by hearing from others, perceptions of participants are likely to change (Finch *et al.*, 2014). In this study, three focus group discussions (FGDs) per community were carried out to explore the prevailing conditions of the population and their socio-ecological systems (Table 8.1). All the FGDs were audio-recorded and transcribed exactly. Thematic analysis was employed to identify emerging issues from the data.

Table 8.1 Characteristics of the FGD participants in Zango and Kofa communities.

Community	**Highest education (%)**	**Type of employment (%)**	**Age range (%)**
Zango (n=23)	Tertiary (39.1)	Farmer (26.1)	18-34 (52.2)
	Secondary (4.3)	Farmer/trader (30.4)	35-50 (30.0)
	No education (56.5)	Farmer/civil servant (43.5)	51 & above (17.4)
	Tertiary (21.4)		
Kofa (n=28)	Secondary (14.3)	Farmer (53.6)	18-34 (54.0)
	Primary (14.3)	Farmer/trader (39.3)	35-50 (35.0)
	No education (50.0)	Farmer/civil servant (7.1)	51 & above (11.0)

The FGDs took the following approach modelled after Dang *et al.* (2014a): (i) design and preparation, (ii) participant recruitment, (iii) implementation, (iv) transcription, and (v) data cleaning and analysis.

(i) Design and preparation: the FGDs schedule was developed with questions that emerged from the initial baseline study and other research (Bizikova *et al*., 2009) and was scheduled to take one hour. Questions were framed based on previous experiences of changes recorded. Questions for the vulnerability analysis included:

a. For exposure:
   i. Are you affected by poor rainfall? How?
   ii. Are you affected by high temperature? How?

b. For sensitivity:
   i. Is the effect on the farm?
   ii. Is the effect on livestock?
   iii. Is the effect on household?
   iv. Is the effect on the village? And,

c. For adaptive capacity:
   i. What have you done to manage this exposure?
   ii. What assets do you possess to help you manage the exposure?
   iii. Do you think it was sufficient/effective?
   iv. Could you have done better given any form of help to manage these problems?
   v. What do you think can be done?
   vi. Who makes decisions for adaptation in your household?

(ii) Participant recruitment: Group sizes and composition for FGDs have been suggested to vary from 8-12 (Steward and Shamdasani, 1990), 6-10 (Morgan, 1997) and 9-11 (Dawson, 2009), as odd numbers prevent people from pairing up in breakaway conversations. Participants were randomly selected based on age and gender from the initial participants in the baseline study into young farmers (18-34 years), older farmers (35 years and above) and women farmers (of all ages). Discussions were held with a total of twenty-three participants in Zango (ten youth, seven women, and six older male farmers) and twenty-eight in Kofa (eight youth, twelve women and eight older male farmers).

(iii) Implementation: The FGDs were carried out by an experienced moderator familiar with the topic of discussion in the language of the participants (Hausa). The sessions were audio-recorded. Additionally, summaries of relevant points were taken by using cardboard and A4 papers to highlight issues for discussion. Furthermore, different colour-marker pens were used and initials of contributors were used to represent their opinions. These were later used to cross-check emerging themes and sub-themes from the thematic analysis.

(iv) Transcriptions: Audio recordings were transcribed verbatim and translated from the local language (Hausa) to English by the corresponding author into text after repetitive listening to the audio recordings. Three transcriptions were developed per community representing the separate groups.

(v) Data cleaning and analysis: from the transcribed text, data were coded into themes and sub-themes using the Nvivo qualitative data analysis software. Frequency counts for the coded themes were obtained and analysed.

8.3.1 Limitations of the qualitative methodology

A qualitative approach to vulnerability assessment has been critiqued by positivist thinkers as being informal and subjective. And that different method of assessment from different epistemologies could provide findings that are inconsistent thereby misleading policymakers (Reed and Stringer, 2016). This limitation was overcome by triangulating the FGDs with historical climate data from the two communities to validate the findings of the FGDs. Secondly, this method was considered important in understanding local adaptation strategies as opposed to model studies.

8.3.2 The case study communities

Zango is an arid farming community identified as vulnerable to climate change, and desertification (Abiodun *et al*., 2011) while Kofa receives higher rainfall but also is relatively dry making it a good comparator for Zango. Climate change scenarios for Zango suggest that maximum temperature will increase, minimum temperature will decrease and heat waves will become more common, in contrast, the future scenarios for Kofa were less clear based on projections available (Abiodun *et al*., 2011). Indeed, participants in Zango claimed to have experienced higher temperature regimes compared to Kofa community as shown in the results from a perception study of farming households in the two communities (Chapter 5) (Section 5.5.5). On the other hand, Kofa participants perceived decrease in the frequency and amount of rainfall. Although long-term temperature data for the growing season did not show much difference between the two communities (Figures 8.1 and 8.2).

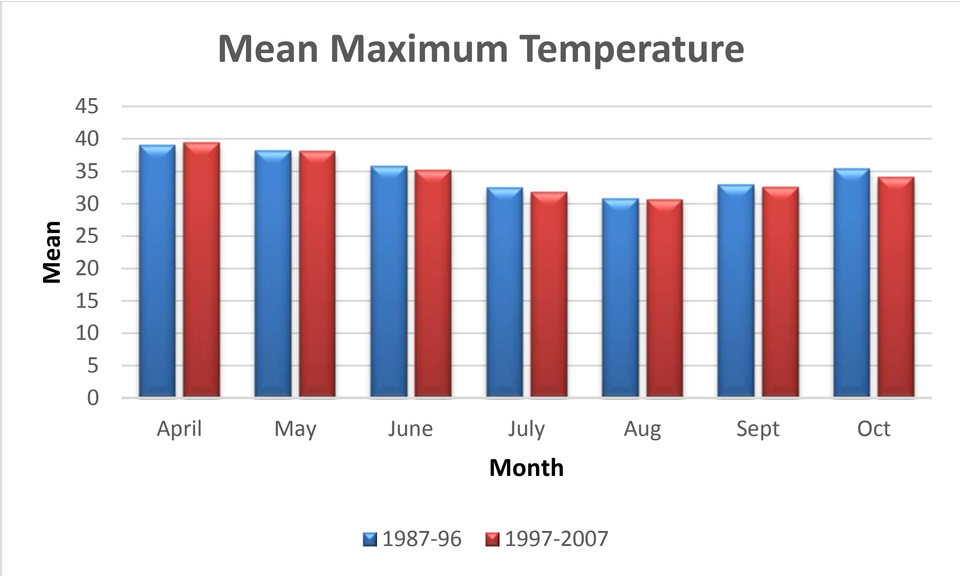


Figure 8.1 Mean Maximum Temperature for the periods 1987-96 and 1997-07 for the growing season for Katsina (a proxy for Zango).

Data source: NiMet (1987-2007).

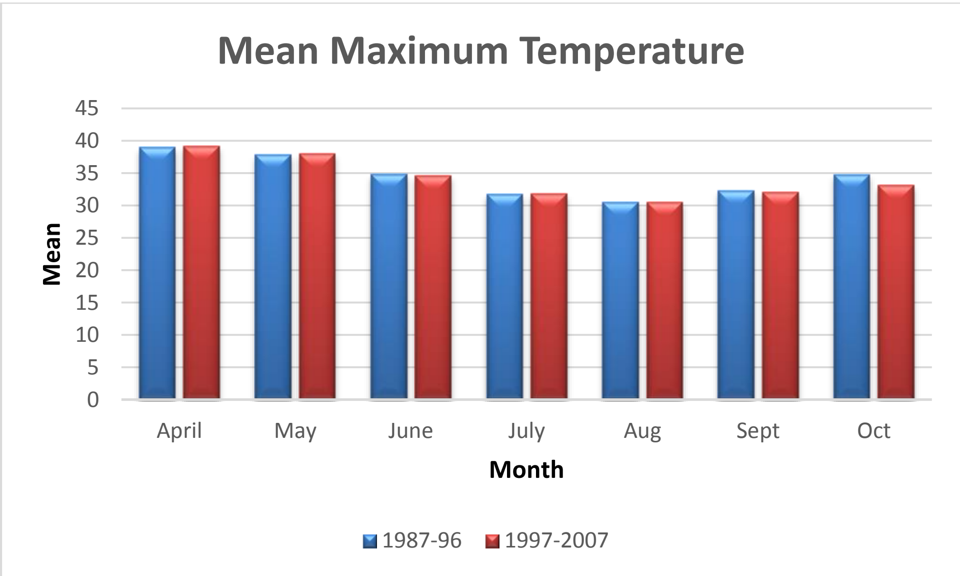


Figure 8.2 Mean Maximum Temperature for the periods 1987-96 and 1997-07 for the growing season for Kano (a proxy for Kofa).

Data source: NiMet (1987-2007).

Rainfall predictions for this region, suggest rainfall will decrease, the time of onset prolonged and length of the raining season being shortened (Abiodun *et al*., 2011) which is in line with rainfall patterns observed in Zango; however, the predictions for Kofa are not well understood (Figures 8.3 and 8.4). Summing monthly data for the growing season shows between season variability (Figure 8.5). Although 21 years data for rainfall is not a sufficient period to assess climate change, it was considered a relevant period to link to farmer experiences of rainfall variations during their farming lifetimes.

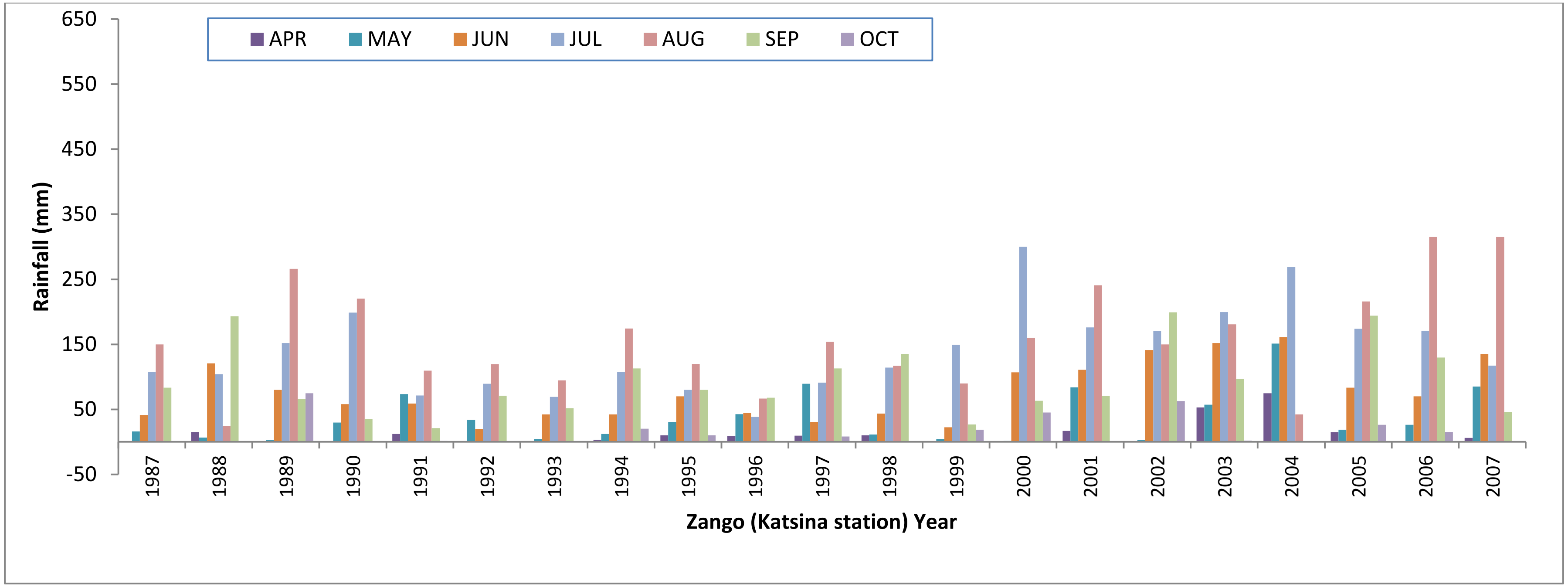


Figure 8.3 Average monthly rainfall amount for Katsina station (a proxy for Zango community) 1987-2007.
Data source: NiMet (1987-2007).

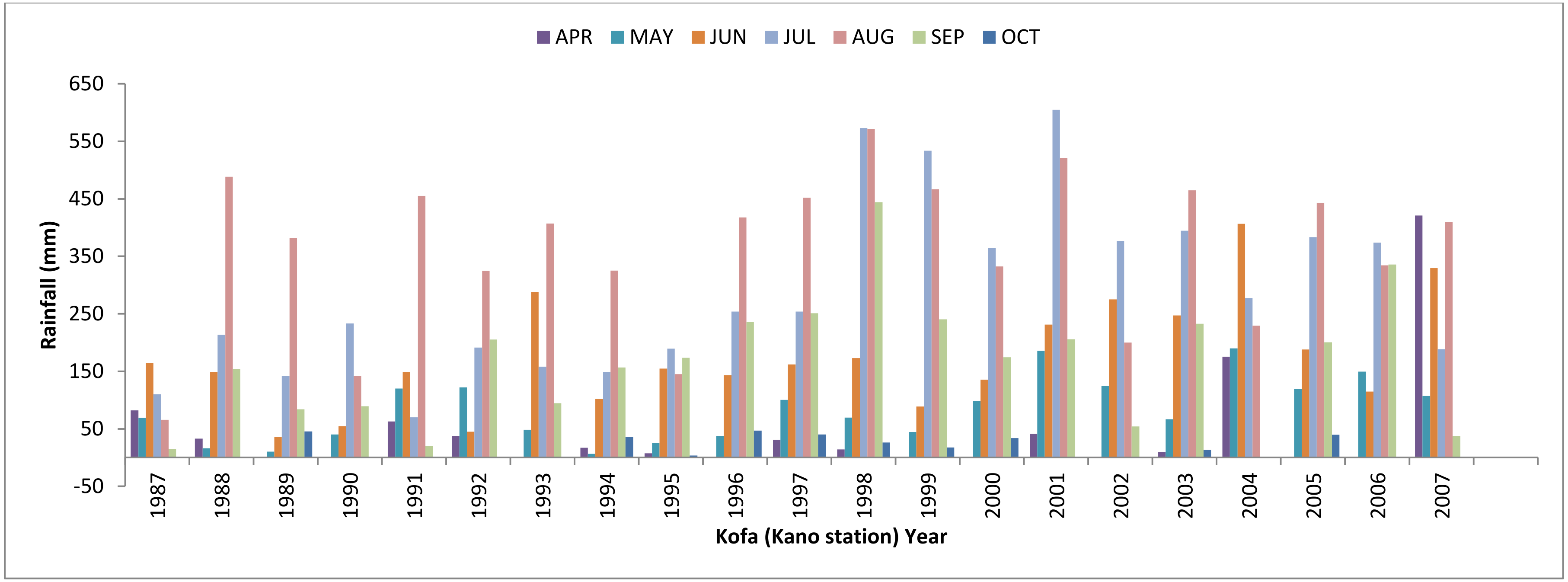


Figure 8.4 Average monthly rainfall amount for Kano station (a proxy for Kofa community) 1987-2007.

Data source: NiMet (1987-2007).

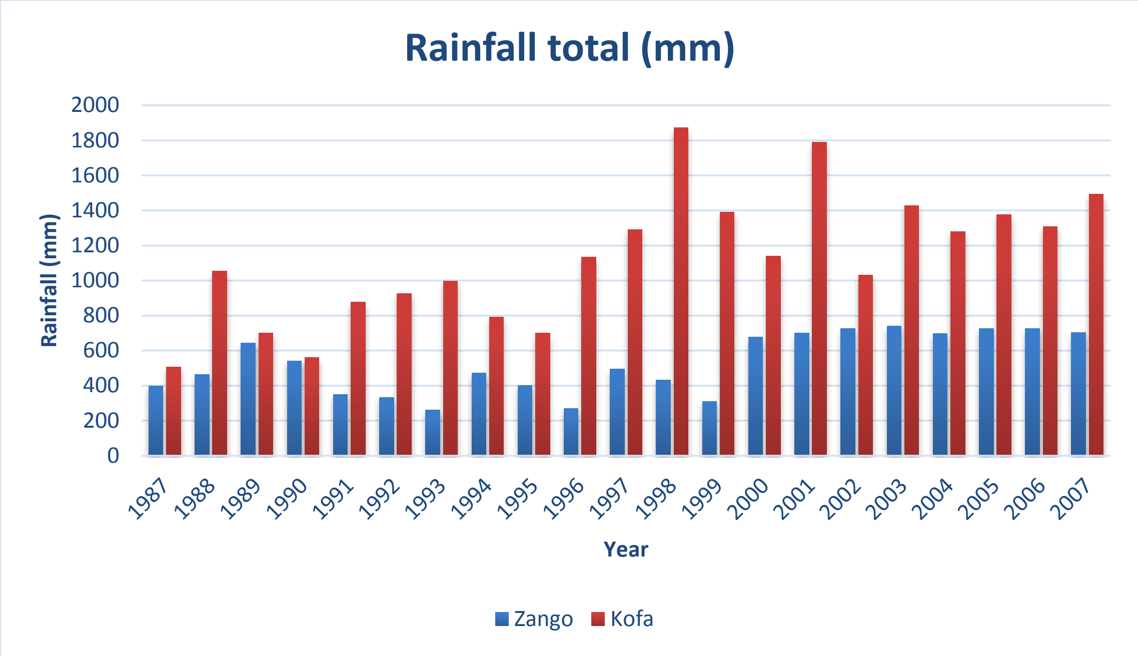


Figure 8.5 Total rainfall for the growing seasons for Zango and Kofa (1987-2007).
Data source: NiMet (1987-2007).

8.4 Results and discussion

The results of this study are presented based on the vulnerability framework adapted from (Reed and Stringer, 2016) which comprises exposure, sensitivity and adaptive capacity.

8.4.1 Exposure

Participants in both Zango and Kofa expressed levels of exposure in diverse ways: first in terms of yield loss due to early cessation of rainfall, secondly yield loss due to temperature variability for example as witnessed in vegetable yield losses in Kofa community. Some participants in Zango established links between rainfall fluctuations and temperature rises arguing that the variables were related, they concluded that a shortage of rainfall leads to increased temperatures. While some farming households in both communities acknowledged being exposed to the effects of the climatic changes, they could not specifically express the extent of the effects as evidenced by short responses such as ‘yes’ with no further explanations when probed further. This could be due to poor knowledge or awareness of the effects of the climate change or just a reluctance to express themselves publicly. The two communities mainly differed in terms of the amount of rainfall in the growing season with rainfall in Zango being much lower than that of Kofa. In an earlier baseline study (Chapter 5) (Section 5.5.5), although temperature data does not show any significant trend, Zango community participants generally perceived changes in weather patterns in terms of increased temperature while Kofa participants perceived rainfall reduction as the signs of the climate changing although this is not definitive according to climatic data (Figures 5.5 and 5.6). Indeed, in Kofa community, inadequate rainfall was their prominent concern.

The assets maintained to address exposure to climate change along with the participants' views on support needed was identified (Table 8.2). No assets to combat exposure were found for the Zango FGDs while some participants in Kofa relied on crop savings and on the more traditional tactic of using livestock as an insurance (Batterbury and Mortimore, 2013). It should be noted, however, that assets are not the only requirement for building adaptive capacity to manage vulnerability or sensitivity as some social skills that enhance adaptability are also very central. Such social skills include perception and awareness about the existence of the source of vulnerability which has been found to lead to adaptation behaviour (Section 5.7).

Table 8.2 Assets possessed and additional support needed for managing exposure.

Community	Assets	Additional support needed
Zango	-	Support with fertilizers, support with early maturing seeds, herbicides, subsidies and loans.
Kofa	Crop savings, livestock	Business and farming support, dams, livestock, early maturing varieties, fertilizers, herbicides, improved varieties of crops.

8.4.2 Sensitivity

Reed and Stringer (2016) suggest that land degradation and climate change interactions have the potential to affect livelihoods significantly through their impacts on 'provisioning services' emanating from fresh water, agriculture and forestry systems. This is evident in the reduced rainfall and increased temperature condition of the communities most especially Zango where rainfall is inadequate for a successful cropping season in some years. In agriculture, crop sensitivity to drought is dependent to a high extent on the soil characteristics and irrigation access (Wilhelmi and Wilhite, 2002). All the participants in the Zango-youth FGD acknowledged that climate change has effects on their livestock, while all participants for the Kofa women group agreed climate change has effects on their farms leading to loss of yield thereby making food expensive. This was supported by the other groups (older and youth groups in Kofa), as almost all participant groups reported that failure of rainfall leads to loss of animal feed and consequently loss of manure (for fertility building). This is a sign of community norms playing out as the youth and men are mostly responsible for the livestock management in both communities; while the women engage in some crop production in female-headed households or in cases where the female respondent is an older woman. Men mostly control the livestock assets which serves as a source of income diversification and manure for soil fertility improvements. In terms of effects of rainfall shortages on households and buildings, some groups (Kofa youth and women) asserted that farms and humans are affected due to drying up of wells at homes making water unavailable for domestic use and small-scale irrigation.

8.4.3 Adaptive capacity

Climate change is expected to worsen food insecurity in regions affected by Desertification Land Degradation and Drought (DLDD) in the absence of proper adaptation as increasing adaptive capacity helps in resilience enhancement (Reed and Stringer, 2016). Adaptive capacity was found to be lacking in both communities in this study. This is in contrast to the mainstream belief that adaptive capacity related to development plans and well-being is key to climate change adaptation strategies in natural resources dependent areas (Adger, 2001).

In terms of adaptation decision-making, in Zango and Kofa communities, a consensus was almost reached on the role of the household head in making decisions on adaptation. This is in conformity with Irohibe and Agwu (2014) where they reported household heads were responsible for decision-making for adaptation against climate change in Northern Nigeria. Although in a few cases, household heads confer with their spouses and elderly children. Religious and traditional leaders also play a role in terms of community adaptation decision-making in these communities. This is reflected in the attitude about climate change being "caused by God" which was frequently quoted as the mainstream belief in the two communities. This is supported by some direct quotations from participants when questions about what was done to adapt, responses recorded were:

> *God helps* (All participants-Kofa women FGD);
>
> *We only prayed* (I.D 11- Kofa women FGD);
>
> *We pray* (All participants for Kofa youth FGD; and-Zango elderly and women FGD);
>
> *We make sacrifices and pray* (I.D 8-Kofa youth FGD);
>
> *We join hands with religious leaders to pray* (I.D 4-Kofa elderly FGD);
>
> *It is God that determines what happens* (I.D 1-Kofa elderly FGD);

This belief in God is further buttressed by the perception that poor seasons are a sign of punishment by God as aptly captured by one participant:

> *"When we face rainfall shortages, we feel we have sinned so we go and pray to ask forgiveness and our problem of rainfall scarcity gets solved"* (I.D 7-Kofa youth FGD).

This belief in God is likely to lead to non-adaptive behaviours as adaptability takes into cognisance the human agency in managing resilience in the socioecological systems (Walker *et al.*, 2004). Belief in God as the cause of climate was previously reported in a climate change perception study for Nigeria (Tambo and Abdoulaye, 2013) which aligns with the findings of this study. The existence of an adaptive capacity for climate change adaptation in the two communities appears to be a controversial topic. Despite the belief in 'God' and 'prayer', when probed further and in a different way, some adaptive measures in the two communities appear to exist (Table 8.3). Ignorance of the intention of carrying out those practices could be a plausible explanation for the 'belief' in God and prayer responses. However, the youth group (FGD) in Kofa were not confident about the capacity to adapt based on the assertion that climate change is caused by God suggesting that the next generation may be less wedded to these beliefs and hence more open to taking on adaptive strategies.

Table 8.3 Household climate change adaptive measures used in the two communities.

No.		**Adaptive measures**	**Zango**	**Kofa**
1.	**Agronomic**	Sourced early maturing varieties	Yes	Yes
2.		Dry season farming	No	Yes (women)
3.		Plant trees	Yes (older)	Yes (older)
4.		Early planting	Yes (older)	Yes (older, youth)
5.		Tied ridges	No	Yes (older)
6.		Manure application	No	Yes (older, women, youth)
7.	**Socio-cultural**	We only pray	Yes (older, women)	Yes
8.		Belief in God	No	Yes (older, women)
9.		We make sacrifices	No	Yes (youth)
10.		Borrow food from neighbours to repay in good season.	Yes (older)	No
11.		Report to extension agents	No	Yes (women)
12.		Did nothing	No	Yes (women)
13.	**Economic**	Sell livestock	No	Yes (women, older)
14.		Fall back to business	No	Yes (older)
15.		Livelihood diversification	No	Yes (women)
16.		Sell my assets	Yes (older)	No

According to Walker *et al*. (2002) adaptive capacity lies in facets of creativity, innovation, memory, flexibility, and variety of natural components and human abilities as displayed in both communities (Table 8.3). Adaptation strategies whether in the form of planned government investments or reactive responses to environmental and economic conditions is not a global issue but individual collective actions at the local level (Adger, 2001). Hence, the agency of farmers is a precursor to a successful adaptation as social networks are also explored for adaptation such as borrowing from neighbours to repay in the good season which was similarly reported by (Osbahr *et al.,* 2008). One approach is to use improved seeds to enhance adaptive capacity; one of the participants in the Youth group in Zango (I.D 6) reported that:

"if we don't have improved seeds and fertilizer is not applied on our farms, it will lead to losses".

However, if fertilizers are applied and rainfall shortages are encountered, it leads to burning of crops and consequently losses that were meant to be avoided by the fertilizers application. Hence, the need for precision application of the fertilizers linked to weather observations for optimum benefits.

Diversification supports the resilience of livelihoods in the short term through risk spreading as some households depend on remittances from their sons working away from home, however, it does not guarantee long-term climate change adaptation (Osbahr *et al.,* 2008). Abson *et al.* (2013) in a UK agricultural landscape diversity study corroborated this by reporting that diversification of land use had a positive correlation with the resilience of agricultural returns when uncertain environmental and market conditions were encountered. Hence, 'increasing diversity of agricultural systems' could increase adaptive capacity (Urruty *et al.,* 2016) for farmers to employ to manage present or future environmental challenges (Nelson *et al.*, 2007). How this can be achieved is further explored in the next section.

8.5 Vulnerability or resilience

Vulnerability and resilience are two opposing forces, reducing vulnerability enhance resilience while also adding two dimensions; time and dealing with uncertainties which bring to the equation the place of adaptive capacity (Gitz and Meybeck, 2012). As found in this study, Zango households are more vulnerable compared to their counterparts in Kofa due to their more marginal conditions and complete dependence on rain-fed agriculture (Appendix 2a).

Vulnerability to environmental variability cannot be separated from resource use as it is caused by deliberate or unintended human action that portrays 'self-interest and the distribution of power, in addition to interacting with physical and ecological systems' (Ribot, 2010). Vulnerability is subjective and depends largely on the capability of the subject facing risk to cope with it (Mehar *et al.,* 2016) as some systems and human populations are more vulnerable compared to others (Reed and Stringer, 2016). It is generally argued that the presence of adaptive capacity leads to resilience while the absence of it results in vulnerability. Knowledge and awareness of the risk support preparations towards managing risk in both communities (Table 8.4).

Table 8.4 Climate change awareness and knowledge.

Community	Local awareness	Global awareness
Zango	-Rainfall fluctuation affects farmers in our community. -Planting seasons have changed as experienced now. -Rainfall shortages have affected our farms. -Our cowpea and groundnuts have been affected by pests & diseases. -Our crops have been burnt due to poor rainfall. -We experienced floods.	In the neighbouring Niger Republic, we hear of how rainfall is insufficient. -In the Niger Republic, people have experienced loss of livestock and other assets which led people to flee from their communities. -Desertification (Hamada*) is been experienced in the Sahara (Niger).
Kofa	-We experience poor yields and pests' infestation is higher on our farms unlike in the past. -The poor performance of onions on our farms.	-We hear of poor rainfall in neighbouring states. -We experience colder weather than in the past. -We hear on the radio that climate change is happening elsewhere.

*Hamada is Hausa word for desert encroachment.

While some adaptive measures exist in Zango and Kofa, the dominant perception is that of belief in the supernatural as the source of the climate change which was suggested by the participants of the FGDs to be a consequence of their 'sins' or wrong doings. Such ignorance could lead to denials or maladaptive behaviours which could result in increased vulnerability (Grothmann and Patt, 2005; Reed and Stringer, 2016). Households in both communities have knowledge of local and global climate change experienced by them and their counterparts in other locations such as the Niger Republic as expressed by the Zango households (Table 8.4). In contrast to knowledge availability, the complex nature of social and ecological systems mostly make it challenging in practice to determine relative susceptibility of certain people and places in such a way that appropriate information for decision makers is provided (Luers, 2005).

In the past few decades, conservation farming practices have been found to be favourable means of agricultural resilience building against dry spells and for improving soil fertility (Lal, 1997). Such resilience is dependent on spatial, temporal and social scales as (Carpenter *et al.,* 2001: 767) states: ‘socioecological system can be resilient at one-time scale because of the technology it has adopted’; while in other times it could be non-resilient. Hence, the participatory co-learning in the previous chapter (Chapter 7) served to provide technology for resilience enhancement in Zango and Kofa. Regions vulnerable to climate change also experience other stresses that impact on the sensitivity, exposure and adaptive capacity (IPCC, 2007). Historical rainfall and maximum temperature records for both communities (Figures 8.1, 8.2, 8.3 and 8.4) also suggest exposure to climatic variation which could lead to vulnerabilities.

Vulnerability analysis that aims to contribute to practical adaptation measures does not make presumptions about the existing levels of exposure and sensitivities in a community nor does it assume to understand the determinants of adaptive capacity in the community without first practically identifying it in the community itself (Smit and Wandel, 2006). Hence, the vulnerability assessment in this study was carried out to satisfy this condition. Smit and Wandel's (2006) interpretation of resilience are based on the capacity to react to shock quickly while choosing the best future path in contrast to the simple notion of resilience as the capacity to return to the former state. The nature of rural areas makes them naturally more vulnerable to environmental and economic shocks compared to large urban areas; this is typical of Zango community which is rural and more vulnerable compared to Kofa that is close to some urban settings. Exposure of the ecological systems of such households to climate change and land degradation together with sensitivity to these exposures in the absence of an adaptive capacity could potentially lead to “regime shifts” and long-term “critical transitions” to new ecological steady states (Reed and Stringer, 2016:41). Sustainable development as advocated in the Brundtland Commission’s report (WCED, 1989) offers a window for reducing susceptibility to climate change through ‘enhancing adaptive capacity and increasing resilience’, although only few sustainability plans take into account aspects of climate change adaptation (IPCC, 2007).

8.5.1 Vulnerability-Resilience Transition Pathway Model (V-RTPM)

Vulnerability is equated with the absence of the ability to adapt (Adger, 2006). However, it is possible to transition systems or households from vulnerability to a more resilient viewpoint as indicated on the V-RTPM proposed by this thesis (Figure 8.6). In this model losses in yield and feed are direct responses to the failure in rainfall and increased temperature which reflects the exposure and sensitivity nature of the socio-ecological system of the study communities to climate-related stimuli as corroborated by Gallopín (2006). However, a sensitive system may or may not be resilient (Gallopín, 2006).

Figure 8.6 **Vulnerability-Resilience Transition Pathway Model (V-RTPM).**
Source: Researcher, adapted from Reed and Stringer (2016)

The V-RTPM highlights that selection, trial, and adoption of good agricultural practices (GAPs) as reported elsewhere (Chapter 7) could potentially lead to the transition from vulnerability to resilience. However, the transition path is not a straightforward one as barriers exist to the uptake of these GAPs. Overcoming these barriers with the right mix of institutional support and climate and environmental change awareness will enhance the process of resilience promotion in the two communities, especially if linked to participatory action planning around the most appropriate GAP's to adopt.

In a related scenario, Luers (2005) argued that two agricultural districts growing similar crops under similar climatic conditions may experience a wide variation in sensitivity to climate variability. For instance, if one system depends on irrigation, sensitivity could be lower compared to the system completely dependent on the rain-fed condition under the same stress. This is the case for Kofa with some form of irrigation compared to Zango with no irrigation thereby confirming the lower vulnerability of Kofa. Managing vulnerability effectively in an unpredictable and dynamic world as Luers (2005: 222) argued:

…will require more than simple analytical tools; it will require a fundamental shift in the way in which local, regional and national decision makers approach resource and development problems.

Good agricultural practices will help in reducing the sensitivity of the system under threat. For example, Adger *et al.* (2005) suggest: *'planting hardier crops that can withstand more climate variability'*, harvesting rainwater in dry areas, tied ridging to hold water in-situ, mulching and cover cropping will promote resilience. This is true as reflected by the findings from the review of GAPs that informed the field training and co-learning (for a detailed review see appendix 1). To support the foregoing argument, IPCC (2012) reported that pronounced exposure and vulnerability are the outcomes of poor development plans for managing environmental degradation. Aligned to this, unequal distribution of resources globally limits developing countries from effectively responding to the vagaries of the climate compared to the developed countries who are equipped resource-wise (IPCC, 2012). This resource limitation could leave rural domains vulnerable despite attempts at reducing risk and climate impacts (Freshwater, 2015). Hence, the need for more financial and technical support to the developing world to adequately prepare and adapt as it will be more beneficial for vulnerable regions to build adaptive strategies in their national development agendas as IPCC (2012: 9) stated:

…national systems are at the core of countries' capacity to meet the challenges of observed and projected trends in exposure, vulnerability, and weather and climate extremes.

Under a high vulnerability and low adaptive capacity scenario, climate change effects may limit the potential of systems to sustainably adapt without 'transformational changes' (IPCC, 2012). In managing the risk of climate change, eliminating exposure may not be feasible as climate change cannot be avoided in Zango and Kofa. This leaves the 'at-risk' populations with the options of self-insurance and self-protection against the risks (Freshwater, 2015).

Taken together, the findings from this study support the assertion that rural development is a process of risk reduction as it tackles the question of 'how much risk to reduce' and 'how best to reduce risk' as tolerance to risk, capacity to mitigate risks and level of exposure are locations and people specific (Freshwater, 2015; Sensier *et al.,* 2016). Overall, the evidence reported above suggest a limited capacity to adapt to environmental challenges in the two communities leading to a vulnerable situation in most cases as Reed and Stringer (2016: 43) argued:

"If the system of focus is exposed, sensitive and unable to adapt effectively to the effects of land degradation and climate change, then it will not be able to maintain its essential functions, identities, and structures or its ability to adapt to future changes, and it will become vulnerable to land degradation and climate change".

Hence, the need to identify means of enhancing the resilience of farming households and communities.

8.6 Chapter summary

Asset ownership by households are not sufficient for ensuring resilience but rather successful adaptation will very much depend on the capacity of communities and individuals 'to coordinate decision-making, act collectively, foster innovation and experimentation, and exploit new opportunities' (Béné *et al.,* 2016). Climate change will likely alter dryland ecosystems in an unexpected way that have never been previously experienced. Therefore, resilience will be the best approach to tackle such surprises (Carpenter *et al.,* 2001). Doing nothing to adapt to the signs of the climate change as reported by some of the participants in this study is generally acknowledged to be maladaptive as the cost of doing nothing far outweighs the cost of action (Nkonya *et al.,* 2016). In this chapter, the notion of doing nothing was closely linked to religious beliefs, therefore suggesting that any participatory planning will have to be sensitive to belief systems or indeed use analogous religious stories where changes are advocated according to certain doctrines. Results show that adaptive capacity was lacking in both communities, due to belief in God as the cause of climate change. Based on the findings, it is safe to conclude that both communities are vulnerable to climate and environmental challenges. Finally, it is argued that a US dollar invested in degraded land restoration gives a return of five US dollars (Nkonya *et al.*, 2016) thereby creating a strong incentive to take steps towards curtailing land degradation and climate change effects by building greater resilience into the socio-ecological systems at the local level. Therefore, policy should focus more on investments towards degraded land restoration and creating more awareness on the effects of environmental and climate change.

CHAPTER NINE

Discussion summary, conclusions and implications for future research

---

The objectives of this chapter are to:

- Revisit the aims and objectives set in Chapter 1 and link these to key findings in the thesis;
- synthesise the arguments made in the different chapters in order to conclude the thesis through linking of the research results and findings with literature in a broader perspective;
- highlight implications of findings for policy and opportunities for future research and discuss the limitations of the research strategy carried out.

9 Introduction

Climate change impacts will be felt differently across sectors and regions as reported by the UK Government review on the economics of climate change (Stern Review, 2006). Since that report, abundant evidence has shown higher projections of climate and environmental change across the globe most especially for sub-Saharan Africa. These effects are already predicted for North-Western Nigeria including Zango and Kofa communities. Existing traditional management practices in drylands have become unsuitable for managing current and future environmental challenges (Boko *et al.,* 2007; FAO. 2011). This is attributed to poverty and low adaptive capacity that limits decision-making by stakeholders to adopt sustainable land management practices (van Kerkhoff and Lebel, 2006). Also, lack of absolute control over conservation benefits may serve as a disincentive for farmers to adapt. As a result, participatory approaches are proposed as good alternatives for managing environmental challenges in drylands (Bautista *et al.,* 2017).

The best possible scenarios for a hunger-free world in the era of climate change have been proposed in the last decade; however, no consensus has been reached in this regard. At the same time, 'resilience' was introduced as an emerging concept by the development community and was considered a 'buzz word' without any concrete meaning attached; conversely, it was viewed as a way of maintaining relevance by the development community. Later on, definitions were coined by different stakeholders depending on the context in which the terminology was used. The concept has been widely used in different spheres such as in ecological studies (Holling, 1973) and in agriculture to understand ecosystem's capacity to respond to perturbations.

The Millenium Ecosystem Assessment (MEA, 2005) argues that dryland inhabitants must continue to act to achieve 'ecological sustainability' as developments in drylands will continue to be dependent on natural resources through the restoration of ecosystem services (Mortimore *et al.,* 2008). Why is resilience promotion needed? Some scholars argue that GAPs can lead to a range of benefits- food security, climate change mitigation, adaptation and poverty reduction. It is against this background that this thesis examined baseline conditions, perceptions and explored how agricultural resilience could be enhanced among drylands' arable farming households in the midst of climate change using GAPs as a proxy for more resilient farming practices for the Zango and Kofa communities located in an important food producing region of Nigeria. The approach involved participatory strategies for transitioning from vulnerability to resilience through a sustainability lens. By so doing, it is anticipated that farmers were empowered to innovate.

9.2.1 Research Objectives

9.2.1 Research Objectives Five specific objectives were set and fulfilled in this research as follows: (i) to assess the vulnerability conditions of the dryland farmers to environmental challenges and identify opportunities for resilience and poverty reduction; (ii) to examine the extent of use of good agricultural practices by North-western Nigerian dryland farmers and how they are conditioned by extension, culture and the local economy; (iii) to examine and evaluate farmer knowledge and understanding of global and local environmental challenges and attitudes to these challenges; (iv) to select, set up and test prioritised GAPs based on review of evidences and evaluate with farmers the outcomes of the tested GAPs; (v) to appraise the barriers for non-adoption and the process of adoption so that lessons learnt can be transferred.

The baseline conditions of farming households in the two communities informed the qualitative part of the research and served as the basis for the training and co-learning activities. These are discussed in turn.

9.2.2 Objective 1: Vulnerability Assessment of Dryland Farmers

A conceptual framework for a resilient food system in the drylands of northern Nigeria was developed in the previous chapter (chapter 8) as an outcome of the first objective. The conceptual framework presents an analysis of vulnerability and highlights the interplay of various features such as determinants of exposure, sensitivity, adaptive capacity, issues around GAPs adaption, barriers and the roles of institutions in enhancing climate awareness. The framework demonstrates how vulnerable farmers can be transitioned to become resilient. Findings from this study reveal that in both Zango and Kofa, crop and livestock integration being a resilience practice for soil fertility management is ongoing as indicated (Figure 5.7). Despite these good practices, key resilience promotion practices were poorly practiced or not practiced at all in some cases.

The rural areas are naturally more vulnerable to environmental and economic shocks compared to large urban areas. Even though large in geographic size, rural areas have less diversified economies with relatively small populations and, as Freshwater (2015) argues, diversification is key to resilience enhancement. Taken together, the findings from this study support the assertion that rural development is a process of risk reduction as it tackles the question of ‘how much risk to reduce’ and ‘how best to reduce risk’ as tolerance to risk, capacity to mitigate risks and level of exposure are locations and people specific (Freshwater, 2015; Sensier *et al.*, 2016). Trust in God as the cause of changes in weather conditions as advocated by many respondents was considered a maladaptive approach which exposes households to more vulnerability. Overall, the evidence reported above suggests a limited capacity to adapt to environmental challenges in the two communities leading to a vulnerable situation in most cases as Reed and Stringer (2016: 43) argued:

If the system of focus is exposed, sensitive and unable to adapt effectively to the effects of land degradation and climate change, then it will not be able to maintain its essential functions, identities, and structures or its ability to adapt to future changes, and it will become vulnerable to land degradation and climate change.

Hence, the need to identify means of enhancing the resilience of farming households and communities, which has been proposed in chapter eight.

9.2.3 Objective 2: Household baseline conditions and adoption of GAPs in north-western Nigerian drylands

Current practices in the study areas were assessed to understand the baseline conditions of the farming households. Good practices for farming existed with the exception of practices for improved water management. The practices absent are critical for resilience management in the drylands, thereby potentially making smallholders vulnerable to environmental change if not properly tackled in both communities. Hence need exists to introduce practices for water management in these communities that are location appropriate for these farming households to be more resilient. Adaptation practices that were autonomous included: business diversification, integrating crop with livestock, early planting date, seeking temporary jobs and migration to certain extents (see appendix 1a). However, migration (cin rani)[11] that has been

[11] A Hausa word for migration.

widely reported in the northern Nigerian drylands' literature (e.g. Mortimore and Adams, 1999; Mortimore *et al.*, 2000; Mortimore and Adams, 2001; Mortimore, 2009) as an adaptation strategy to variability in the past was no longer an important strategy in Zango or Kofa. This was because developments have been experienced in the drylands according to the farming households engaged thereby changing the adaptation dynamics in northern Nigerian drylands and also due to the opportunity cost of rural labour. Some of the developments include access to information and communication technologies (ICTs), other small scale businesses linked to ICT, transport business and dry season farming within the communities especially in Kofa. Additionally, young household members who hitherto were involved in migration do no longer feel safe going out in search of jobs due to the insecurity in Nigeria occassioned by the Boko haram insurgency, farmer-herders' clashes and rampant kidnappings in the country. Also, children now go to school in preparation for 'better jobs' as this has seen the level of school enrolment improve. The enrolment in schools however, have constraint household labour availability for farm activities forcing household heads to hire labour. These obvious changes in previously reliable adaptation strategies, makes it an urgent need to have new approaches for drylands adaptation for resilience promotion in the north-western Nigerian drylands, amidst weather fluctuations and consequently climate change. Exploring baseline conditions thus becomes important in the co-learning process as this provided the necessary background for addressing the rest of the research objectives.

9.2.4 Objective 3: Farmer knowledge and perceptions of environmental challenges and attitude to adaptation

In terms of perceptions, households in the different communities perceived climate change to be happening based on their specific vegetation condition as indicated by the results of a Principal Component Analysis (PCA) of the baseline data (Section 5.5.5). This was further confirmed by the results of the focus group discussion (Section 8.3.2). The perceptions of each community were also consistent with time series climate data (temperature and rainfall) from 1987 to 2007 (Figures 8.4 and 8.5). Although 21 years data is not a sufficient period to assess climate change, it was considered a relevant period to link to farmer experiences of rainfall variations during their farming lifetimes. Perceptions in both communities are based on lived experiences of environmental challenges such as increased desertification, sandstorm, late onset and early cessation of rain that can be linked to a changing climate; however, this was more keenly sensed in Zango community. Farmers who perceived increased temperatures and decreased rainfall as the signs of a changing climate on the upper part of the quadrant in both Zango and Kofa respectively (Figures 5.5 and 5.6) were selected for the co-learning activities to serve as lead farmers. The increase in temperature and decrease in rainfall perceived by households in the two communities is consistent with a previous climate change perception study for Nigeria (Odjugo, 2010) that found temperature increases and a decrease in amount and duration of rainfall spanning the last century. Decreased rainfall was linked to increased pest infestations according to some household heads in Kofa community. However, variance measured for perception in terms of pest and disease was the lowest in this study (Figure 5.4). It will be interesting to further investigate the cause of the low variance for this important variable recorded.

While it is important to advocate GAPs for adoption and adaption for resilience enhancement, it is also crucial to understand the cognitive determinants of adaptation behaviour of farmers so that adaptation can be facilitated through the promotion of such determinants by policy formulators. Further interrogation of the data led to an exploration of the Theory of Planned Behaviour (TPB) to examine the influence of perception on adaptation behaviour to climate change. This thesis argued that perception determines attitude towards the intention to adapt to climate change in both communities. Subjective norms also significantly determined intention to adapt to environmental challenges by participants in Kofa compared to Zango. Perceived behavioural control, however, did not determine intention to adapt in both communities (Section 5.7). This could be attributed to responses emanating from some respondents from the baseline survey and in-depth interviews. Most respondents argued that climate change was caused by God (a supernatural power) and that they have no control over it. Hence, this leads to maladaptive behaviours. Farmers' attitude influenced adaptation to environmental challenges in this study in contrast to what has been previously reported in the literature as the determinant of adaptation behaviour (Wicker, 1969 cited in Terry *et al.*, 1999). While positive results were recorded in terms of attitude influencing adaptation, this study was conducted prior to adoption as opposed to studies that previously explored determinants of intention after adoption (Meijer *et al.*, 2015). It will be interesting to explore determinants of intention to adopt practices in the future to compare findings pre and post adoption of the innovation facilitated in line with other studies such as Meijer et al. (2015).

9.2.5 Objective 4: Farmer engagement and role of extension on resilience enhancement

Extension has a critical role to play in resilience promotion in the era of climate change, as information and learning are critical to the process of adapting to this change. Current extension methods, models and extension agent-farmer ratios are grossly inadequate to achieve the desired goal of resilience promotion. It was found that extension was inadequate in the two study communities and this was not surprising due to the high farm household-to-extension ratio reported in the two communities (Section 6.6.1-6.6.5) which corroborates literature findings (e.g. Oladipupa *et al.,* 2014). Perspectives on the sufficiency of extension in both communities differ among delivering stakeholders (research and extension agents) and farming households. Also, the existing knowledge gap around climate resilient GAPs of current extension agents is a potential contributor to this inadequacy of extension. Hence, under this circumstance, a new strategy to extension will be invaluable. As agriculture has increasingly become knowledge-intensive, rural people will require reliable and current information to drive their household and community economies. Such information should be location specific. This was further underpinned by the results of the Delphi study (Chapter 6-section 6.3) where experts achieved consensus on the GAPs suitable for tropical drylands and the best methods for engagement which informed the co-learning activity engaged with the farmers (Chapter 7).

Farmers in the developing world are often considered to be very backward and poor compared to the developed world, where farmers could be more successful and richer; the current extension approaches in developing economies seem to have done little to change the way smallholders operate. This is especially true in cases where conflict exist between innovation versus culture and tradition (Rogers, 1999). For example, in this study, women's participation in farming in Zango and Kofa was minimal due to cultural and religious reasons that hinders them from actively participating in agriculture. This is in contrast with mainstream beliefs about women being pivotal in smallholder agriculture in the developing world (De Schutter, 2013).

It is now widely understood that agricultural productivity processes cannot be sustained by innovations introduced alone, but rather through the social dynamic of farmer engagement on the management and coordination of ecological processes (Leeuwis, 2004). Farmers lead transformation and are a source of knowledge. They have opportunities to transform their environments and farming systems to achieve food and ecological security. This can be achieved through improving their skills, knowledge, and perceptions (FAO, 2016a) for which the GAPs co-learning activity was targeted in this study. This is contrary to previous studies in northern Nigerian drylands (Mortimore and Adams, 1999) that report farmers do not require external support to become resilient. Findings from this study reveal farmers need support to be resilient to climate change as they are increasingly experiencing environmental conditions that are beyond their collective experiences.

9.2.6 Objective 5: Co-learning and barriers to adaption of GAPs for resilience

Significant work has been published on the determinants and barriers to uptake of innovations in agriculture (Rogers, 1995; Rogers, 2003; Adesina and Chianu, 2002; Giller *et al.,* 2009; Altieri and Nicholls, 2012; Meijer *et al.,* 2015; Burbi *et al.,* 2016; Reed and Stringer, 2016). Despite the efficacy of GAPs in resilience promotion, adapting them is not a very straight-forward issue. Findings from this study highlighted different barriers and their interactions that hinder the adaption process ranging from psycho-social, cultural, institutional, economic, and environmental to physical barriers. Barrier management could be likened to risk management. Due to lack of trust in some of the practices advocated, farming households tend not to be adapting the practices wholesomely on their farms. Rather it was advised that 10 percent of the farms be used for trial and when satisfied with the outcome, the practices can then be out scaled to the whole farm. In order cases, short term annual practices such as drought tolerant crop varieties are often adapted as opposed to practices with long term benefits such as agroforestry. Similarly, farmers have a poor understanding of climate science, which could hinder GAPs uptake. Hence, the need for more awareness and education to increase uptake of GAPs through a participatory way. As part of the co-learning activity, there was an element of gender mainstreaming where women were engaged in vegetable production using water harvested to water the gardens to produce the basic food requirements of the household. Water harvesting is aimed at reducing the vulnerability of the household to external shocks. The women do not need to go outside the house as the vegetable garden is in the homestead. A similar practice was found in a study for technology adoption in Bangladesh where women were involved in vegetable production at home to reduce vulnerability (Meinzen-Dick *et al.,* 2004). The results of the pre- and post-co-learning exercise also indicated that confidence to manage environmental challenges in the two communities were improved. This implies that a training and co-learning engagement could potentially lead to improvements in resilience practices. This corroborates the assertion by Rogers (2003) that knowledge development is key to innovation uptake and understanding current attitudes and knowledge of farmers based on agricultural technology and how they evolved could lead to the design of projects that are location specific; and also, the redesign of existing technology to suit the needs of farmers for greater adoption and sustainability (Meijer *et al.,* 2015). Issues of power relations could presumably hinder the participatory co-learning process most especially if women are involved with men in a group training and engagement. However, this challenge was tackled through separate engagement and training on home garden vegetable production for the women group alone in both communities.

9.3 Agriculture, food security, environmental challenges and poverty nexus in Zango and Kofa

It has been observed that the intrinsic low productivity of drylands together with other adverse conditions could lead to poverty (Safriel and Adeel, 2008). Also argued in several quarters is the assertion that a direct correlation exists between agricultural development in Nigeria and poverty levels, i.e any policy that targets poverty reduction should be hinged on agriculture as agricultural development is a 'sine qua non' for poverty alleviation (Rogers, 1999; Shiferaw *et al.,* 2009). Most households are concerned with food security and income objectives first before considering environmental stewardship (Reardon and Vosti, 1997a). Since households depend on rain-fed agriculture for their production, inability to manage drought challenges will affect the food security of these households. Agricultural intensification using fertilizers, large-scale irrigation and pesticide could result in salinization and biodiversity loss in the long-term (De Haen, 1997). As most poor people in Africa are rural, depend on agriculture, and invest the largest percentage of their income in purchasing food, making African agriculture work could potentially provide solutions to the 'problem of African poverty' (Scoones *et al.,* 2005:1). Hence, an African adage holds: '" that once the problem of food is addressed in the life of a poor fellow, the poverty level has been substantially solved"' (Rogers, 1999). Livelihoods deterioration, occasioned by diminished crop productivity, extreme climate events, and political instability has historically led to the migration of human populations in considerable numbers with attendant political, socio-economic and environmental consequences (Myers, 1993). For instance, the sub-Saharan African drought of the late 1960s together with the poor use of marginal lands and weak economies resulted in increased pressure on the drylands ecosystems which failed to sustain the increased population resulting in famines and human migration (Nnoli, 1990). Findings show that solving degradation challenges in both Zango and Kofa using GAPs could potentially result in poverty reduction as productivity will increase, cost and amount of input will decrease, thereby leading to high gross margins for the farmers. While this thesis agrees with previous scholarly research of northern Nigerian drylands on the existing sustainable strategies by drylands farmers, it is pertinent to further understand that these strategies are not sufficient in an event of a future unpredictable climate change, thereby arguing for the integration of GAPs for future resilience to climatic shocks (Figure 9.1). Given that the process of GAPs adoption is a complex and not straightforward process influenced by series of factors, a single theory may be insufficient to analyse decision-making process that fully describes adoption methods (Meijer *et al.,* 2015). Hence the use of different theories in this thesis to understand participating households' decision-making for adaptation to environmental challenges.

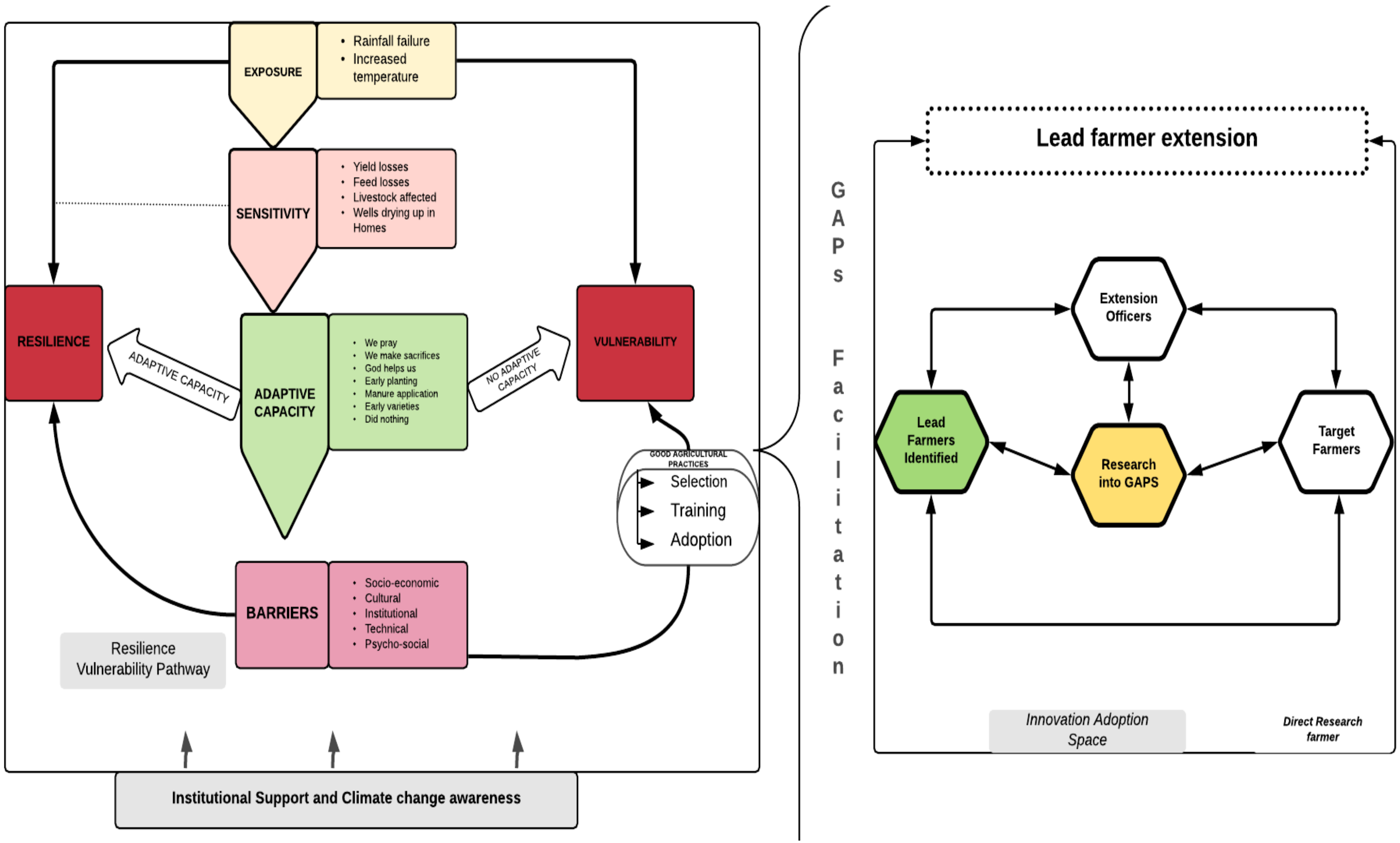


Figure 9.1 Framework for an improved extension for resilience promotion.

9.4 Conclusions

This thesis began by presenting the challenges facing smallholders globally as food security, adaptation, mitigation and poverty reduction objectives are hotly sought after. Drylands smallholders are unlikely to escape the impacts of such challenges. Despite the threat of desertification in dry areas and the notion of its irreversibility, measures can be taken to reverse the process before it gets to the 'desertified' stable state. This will involve biophysical approaches (agricultural improvement and sustainable resources use); policy and socioeconomic measures (stakeholder engagement, extension, and training, investing in renewable energy, efficient marketing, integrating local and scientific knowledge). The failure of the linear model of extension has offered a new vista for a more participatory model of extension. In this thesis, I have looked at the baseline conditions of farmers prior to the co-learning research activity. Prevailing practices showed farming households to be doing very well except on practices critical to resilience promotion such as mulching and irrigation. This thesis also argues that for resilience to be enhanced in the north-western Nigerian drylands in the midst of climate change and to promote food security, a shift in the mainstream approach to drylands management is needed. However, this is not a very straightforward activity. It will entail identifying GAPs for drylands that are site-specific and based on scientific evidence which this thesis has successfully argued. Also, there is a need to engage more and critically observe the adaptation dynamics in the study communities in order to reduce the researcher's influence on the participating households. This deeper engagement will reduce potential biases in the responses obtained.

A process of facilitation of the GAPs' adoption will have to be educational and participatory in approach and must guarantee partnership amongst research, farmers and extension agents. This research therefore, is an excellent example of the role of the researcher as facilitator of knowledge. By this facilitation of farmer engagement, co-learning is being fostered, so that communities can take ownership of their own development. Also, transitioning vulnerable farmers to the resilient phase could be possible through GAPs adaption. However, it will be naive to conclude that the GAPs are sufficient in themselves as constraints and barriers exist. Hence, this thesis argued that overcoming these barriers could allow vulnerable farming households to be resilient.

Empowering people to take responsibility for themselves will be the way forward. Understanding rural farmers' agency is key to this transformation. Additionally, It is not enough to suggest innovations or GAPs that can potentially support resilience enhancement but understanding attitude and behavioural change dynamics among farming households could potentially support the process of innovation adaption. Having argued in the different chapters on the necessary ingredients to resilience enhancement in the drylands of north-western Nigeria, I believe this thesis has done justice to this timely topic in an exhaustive synthesis of all the chapters in the discussion summary section and has answered the questions earlier posed in a coherent manner. This brings us to yet another question as to where do we go from here?

9.5 Policy implications of research

The knowledge developed from this thesis will be very relevant if situated in the context of the Nigerian environment and development policy domain. Nigeria ratified the three UN conventions (UNFCCC, UNCBD, and UNCCD), and against this backdrop, the strategic aims of developing agriculture under climate change regime were proposed. National Action Programme, National Adaptation Plan of Action and National Resilience Framework were developed to address different climate change commitments in Nigeria.

While the focus of this thesis is partly on good agricultural practices and barriers to adoption and adaptation, the findings from this thesis have implications for effective resilience promotion to climate and environmental change in Zango and Kofa communities. Moreover, although the findings of the research are place-based, in a rural developing country context, lessons learned can be transferred to other developing rural areas with similar characteristics; e.g. other sahelian drylands.

Findings from this thesis contribute to attaining the third strategic objective of the Nigerian National Agricultural Resilience Framework (NARF) aimed at 'improving productivity through training community and grass root farmers on land and water management strategies'. As such this will contribute towards the goal of attaining agricultural resilience in Nigeria.

The findings could also support policymakers to design programmes that will influence attitude towards an intention to adapt to climate change, thus reducing the impact of climate change and degradation to livelihoods of vulnerable households. Sustainability should focus on improving livelihood and food security of rural families and not on a wider forestry or agriculture sector thereby alleviating poverty. More production should be encouraged in the more favourable ecological zones and resources conserved in the marginal environments.

Drylands of north-western Nigeria could potentially be utilised for alternative uses if agriculture fails. This includes tourism, renewable energy generation such as solar, biofuel production from crops that are drought tolerant such as jatropha.

Policy for mitigation of climate change impacts on Nigerian agricultural sector should focus on understanding climate impacts on the country's agricultural resource base, building capacity in extension agents due to their current knowledge gaps including developing better participatory skills and on working with lead farmers.

9.6 Limitations and opportunities for further research

While I have made a significant effort in this thesis to answer the objectives set in the beginning in chapter one, more questions have arisen in the process of carrying out this research which I propose to be considered for further studies as follows:

- Further studies should consider a more deductive approach to an in-depth application of the Theory of Planned Behaviour to understand farmer behaviour as this study approached this through an initial inductive approach.
- It will be interesting to use other standardized sampling techniques other than purposive sampling to see if differences in the pattern of responses will be observed. Purposive sampling mostly favours more informed, educated and sometimes wealthier households as opposed to the mostly poor and disadvantaged households. However, other distant communities away from the village centres were visited to collect opinions from those isolated households to reflect divergent opinions.
- Good agricultural practices have climate-smart benefits, hence, it will be interesting to use a tool to measure their mitigation potentials for smallholder enterprises.

- With limited historical climate data for the two communities, policy implications and interpretations resulting from the study should be treated with caution; it should be treated as suggestive rather than conclusive.
- Although the Delphi study has succeeded in capturing the views of experts from a broad disciplinary perspective related to the subject of study, it will be interesting for further studies to consider participants with distinct characteristics from these ones to compare variation in responses.
- This study is limited by the presence of the researcher in collecting evaluation data. An independent evaluation could presumably lead to different responses from the farming households on issues such as lack of trust in the source of information, as this was not highlighted by the participants but highlighted in other studies.
- Large sample size to perform a more robust statistical analysis was lacking due to the drop out of some participants at the appraisal stage. Observation of the results suggests education, age and gender may have an influence on adoption of certain practices. However, data is inappropriate for a correlational analysis as a Chi-square test showed 3 cells (75.0 %) have expected count less than 5 which makes the test inappropriate. Using a larger sample size could overcome this limitation.
- Unlike in the case of a recent study on the determinants of the adoption of multiple innovations to combat climate change in sub-Saharan African drylands (Kpadonou *et al.,* 2017), this study considered single adoptions separately. It will be interesting to explore determinants of multiple adoption of innovation in future.
- It is difficult to obtain meaningful information from a six months post-intervention appraisal since it occurred during the intervention process. More valuable information can be obtained by measuring the level of adoption after the next season thereby helping to determine the sustainability of the intervention.

References

Abiodun, B. J., Salami, A. T. and Tadross, M. (2011) Climate Change Scenarios for Nigeria: Understanding Biophysical Impacts. Climate Systems Analysis Group, Cape Town, for Building Nigeria's Response to Climate Change Project. Ibadan, Nigeria: Nigerian Environmental Study/Action Team (NEST).

Abson, D. J., Fraser, E. D. G. and Benton, T. G. (2013) Landscape diversity and the resilience of agricultural returns: a portfolio analysis of land-use patterns and economic returns from lowland agriculture. *Agriculture & Food Security*. 2(1): 2

Ackerman, F. and Stanton, E. A. (2013) *Climate Impacts on Agriculture: A Challenge to Complacency*. Global Development and Environment Institute, Tufts University.

Adams, W. M. (1991) Large scale irrigation in Northern Nigeria: Performance and ideology. *Trans. Inst. British Geogr. N.S*, 16, 287-300.

Adams, W. M. and Mortimore, M. J. (1997) Agricultural Intensification and Flexibility in the Nigerian Sahel. *The Geographical Journal*. 163(2): 150-160

Adamu, G. K, Yusuf, M. A. and Ahmed, M. (2014) Soil Degradation in Drylands. *Academic Research International*. 5(1): 78-91.

Adenle, A. A., Azadi, H. and Manning, L. (2017) The era of sustainable agricultural development in Africa: Understanding the benefits and constraints. *Food Reviews International*. 1-23

Adesina, A. A. and Chianu, J. (2002) Determinants of farmers' adoption and adaptation of alley farming technology in Nigeria. *Agroforestry Systems*. 55(2): 99-112

Adger, W. N. (2000) Social and ecological resilience: are they related? *Progress in Human Geography*. 24(3): 347-364

Adger, W. N. (2001) Scales of governance and environmental justice for adaptation and mitigation of climate change. *Journal of International Development*. 13(7): 921-931

Adger, W.N, Arnell, N. W. and Tompkins, E. L. (2005) Successful adaptation to climate change across scales. *Global Environmental Change*. 15(2): 77-86

Adger, W. N. (2006) Vulnerability. *Global Environmental Change*. 16(3): 268-281

Adger, W. N., Barnett, J., Brown, K., Marshall, N. & O’Brien, K. (2013) Cultural dimensions of climate change impacts and adaptation. *Nature Clim. Change* 3: 112–117.

Adger, W. N., Brown, K., Nelson, D. R., Berkes, F., Eakin, H., Folke, C., Galvin, K., Gunderson, L., Goulden, M., O'Brien, K., Ruitenbeek, J. and Tompkins, E. L. (2011) Resilience implications of policy responses to climate change. WIREs Clim Change, 2: 757–766. doi:10.1002/wcc.133.

Adger, W. N., Huq, S., Brown, K., Conway, D. and Hulme, M. (2003) Adaptation to climate change in the developing world. *Progress in Development Studies*. 3(3): 179-195

Agbogo, E. and Aja, O. (2011) Analysis of the agricultural policies in the development of the Nigerian economy (1960 - 2010). *Journal of Agriculture, Forestry and the Social Sciences*. 9(1).

AGRA (Alliance for a Green Revolution in Africa). (2014) Africa agriculture status report: Climate change and smallholder agriculture in sub-Saharan Africa. Nairobi, Kenya.

AGRA (Alliance for a Green Revolution in Africa). (2016) Africa Agriculture Status Report: Progress towards Agricultural Transformation in Africa. Nairobi, Kenya

Ahmad, M.-u.-D., Masih, I. and Giordano, M. (2014) Constraints and opportunities for water savings and increasing productivity through Resource Conservation Technologies in Pakistan. *Agriculture, Ecosystems & Environment*. 187: 106-115

Ajani, E. N, Mgbenka1, R. N and Okeke, M. N. (2013) Use of Indigenous Knowledge as a Strategy for Climate Change Adaptation among Farmers in sub-Saharan Africa: Implications for Policy. *Asian Journal of Agricultural Extension, Economics & Sociology*. 2(1): 23-40.

Ajzen, I. (1985) From Intentions to Actions: A Theory of Planned Behavior. **In**, Kuhl, J. and Beckmann, J. (eds.) *Action Control: From Cognition to Behavior.* Springer Berlin Heidelberg: 11-39

Ajzen, I. (1988) *Attitudes, personality, and behavior*. Chicago: Dorsey.

Ajzen, I. (1991) The theory of planned behavior. *Organizational Behavior and Human Decision Processes*. 50(2): 179-211

Ajzen I. (2001) Nature and operation of attitudes. *Annu. Rev. Psychol.* 52:27–58

Ajzen, I. (2002) Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior.*Journal of Applied Social Psychology*. 32: 665–683.

Ajzen, I. (2011) The theory of planned behaviour: Reactions and reflections. *Psychology & Health*. 26(9): 1113-1127.

Ajzen, I. (2015) Consumer attitudes and behavior: the theory of planned behavior applied to food consumption decisions. *Rivista di Economia Agraria*. Anno LXX(2): 121-138

Akande, T. and Ogundele, F. (2009). African food crisis: the Nigerian case study. *Afrint II micro studies*. Ibadan, Nigerian Institute of Social and Economic Research (NISER).

Akinnagbe, O. M. and Ajayi, A. R. (2010) Challenges of Farmer-Led Extension Approaches in Nigeria. *World Journal of Agricultural Sciences*. 6(4): 353-359

Alexandratos, N. and Bruinsma, J. (2012) *World agriculture towards 2030/2050: the 2012 revision.* ESA Working paper No. 12-03. Rome, FAO.

Allouche, J. (2011) The sustainability and resilience of global water and food systems: Political analysis of the interplay between security, resource scarcity, political systems and global trade. *Food Policy*. 36: S3–S8.

Altieri, M. A. (2000) *Modern Agriculture: Ecological impacts and the possibilities for truly sustainable farming.* [online] Available from: http://agroeco.org/wp-content/uploads/2011/02/ecol_impact_modern_ag.pdf [Date accessed: 13/04/2017]

Altieri, M. A. (2010) Scaling Up Agroecological Approaches for Food Sovereignty in Latin America. **In**, Wittman H., Desmarais A.A., and Wiebe N. (eds.) *Food Sovereignty: Reconnecting Food, Nature and Community*. Pambazuka Publishing: 120-133.

Altieri, M. A. and Nicholls, C. I. (2012) Agroecology Scaling Up for Food Sovereignty and Resiliency. In: Lichtfouse E (ed.) Sustainable Agriculture Reviews 11. pp. 1-29. DOI 10.1007/978-94-007-5449-2_1.

Alwang, J., Siegel, P. B., Jorgensen, S. L., 2001. Vulnerability: A View from Different Disciplines. Discussion Paper Series No. 0115. Social Protection Unit, World Bank, Washington DC.

Anderson, J. R., Feder, G. and Ganguly, S. (2006) The rise and fall of training and visit extension: an Asian mini-drama with an African epilogue. World Bank Policy Research Working Paper. 3928. Washington DC, The World Bank.

Andersson, J. A. and D'Souza, S. (2014) From adoption claims to understanding farmers and contexts: A literature review of Conservation Agriculture (CA) adoption among smallholder farmers in southern Africa. *Agriculture, Ecosystems & Environment*. 187: 116-132

Antwi-Agyei, P., Dougill, A. J. and Stringer, L. C. (2015) Barriers to climate change adaptation: evidence from northeast Ghana in the context of a systematic literature review. *Climate and Development*. 7(4): 297-309

Anyamba, A. and Tucker, C. J. (2005) Analysis of Sahelian vegetation dynamics using NOAA-AVHRR NDVI data from 1981–2003. *Journal of Arid Environments*. 63(3): 596-614

Aregheore E.M (2009) Nigeria Country Pasture/Forage Resources Profiles. FAO, Rome.

Ashton, N.J, Arnott, S. and Douglas, O. (1999) The human ecosystems of the Niger-Delta - an ERA handbook. Environmental Rights Action, Lagos.

Ati, O. F., Stigter, C. J., Iguisi, E. O. and Afolayan, J. O. (2009) Profile of rainfall change and variability in the Northern Nigeria, 1953-2002. *Research Journal of Environmental Sciences*. 1(2): 58-63

Ayoola, G. B. (2001) *Essays on The Agricultural Economy 1: A Book of Readings on Agricultural Development Policy and Administration in Nigeria:* Ibadan: TMA Publishers.

Bandura, A. (1977) Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review*. 84: 191–215.

Bandura, A. (1982) Self-Efficacy Mechanism in Human Agency. *American Psychologist*. 122-147.

Bartlett, M. S. (1954) A note on multiplying factors for various chi square approximations. *Journal of Royal Statistical Society*. 16(Series B): 296-298

Batterbury, S. P. J. and Mortimore, M. J. (2013) Adapting to drought in the West African Sahel. In: *Sarah Boulter, Jean Palutikof, David Karoly, and Daniela Guitart* (eds.) in press. Natural Disasters and Adaptation to Climate Change. *Cambridge University Press.*

Batterbury, S. and Warren, A. (2001) The African Sahel 25 years after the great drought: assessing progress and moving towards new agendas and approaches. *Global Environmental Change*. 11(1): 1-8.

Baudron, F., Tittonell, P., Corbeels, M., Letourmy, P. and Giller, K. E. (2012) Comparative performance of conservation agriculture and current smallholder farming practices in semi-arid Zimbabwe. *Field Crops Research*. 132: 117-128

Bautista, S., Llovet, J., Ocampo-Melgar, A., Vilagrosa, A., Mayor, Á. G., Murias, C., Vallejo, V. R. and Orr, B. J. (2017) Integrating knowledge exchange and the assessment of dryland management alternatives – A learning-centered participatory approach. *Journal of Environmental Management*. 195: 35-45

Bayala, J., Sileshi, G.W., Coe, R., Kalinganire, A., Tchoundjeu, Z., Sinclair, F. and Garrity, D. (2012) Cereal yield response to conservation agriculture practices in drylands of West Africa: A quantitative synthesis. *Journal of Arid Environments.* 78: 13-25.

Bayala, J., Sanou, J., Teklehaimanot, Z., Kalinganire, A. and Ouédraogo, S. J. (2014) Parklands for buffering climate risk and sustaining agricultural production in the Sahel of West Africa. *Current Opinion in Environmental Sustainability*. 6: 28-34

Beddington, J., Asaduzzaman, M., Clark, M., Fernandez, A., Guillou, M., Jahn, M., Erda, L., Mamo, T., Van Bo, N., Nobre, C. A., Scholes, R., Sharma, R. and Wakhungu, J. (2012) *Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).* Copenhagen, Denmark. Available online at: www.ccafs.cgiar.org/commission.

Béné, C., Al-Hassan, R. M., Amarasinghe, O., Fong, P., Ocran, J., Onumah, E., Ratuniata, R., Tuyen, T. V., McGregor, J. A. and Mills, D. J. (2016) Is resilience socially constructed? Empirical evidence from Fiji, Ghana, Sri Lanka, and Vietnam. *Global Environmental Change*. 38: 153-170

Béné, C., Wood, R.G., Newsham, A. and Davies, M. (2012) Resilience: new utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. *IDS Working Papers* 2012: 1-61

Benor, D. and Baxter, M. (1984) Training and Visit Extension. The World Bank, Washington D. C.

Bentley, J., Van Mele, P., Kibwika, P., Diallo, H. A., Odour, G., Romney, D. and Williams, F. (2011). *AGRA Extension Support Function Country Reports*. CAB International. Available from: http://agroinsight.com/downloads/Articles-Agricultural-Extension/2011_AE-AGRA-Country-Study-Reports-2011.pdf

Bergman, M. M. (2008a). *Advances in mixed methods research: Theories and applications*. London SAGE: 1-7

Bergman, M. M. (2008b) The Straw Men of the Qualitative –Quantitative Divide and their influence on mixed methods Research. ***In,*** Bergman, M. M. (eds). *Advances in mixed methods research: Theories and applications*. London SAGE: 11-21

Biesbroek, G. R., Termeer, C. J. A. M., Klostermann, J. E. M. and P. Kabat (2011) Barriers to climate change adaptation in the Netherlands, Climate Law 2, 181-199

Bindraban, P. S., van der Velde, M., Ye, L., van den Berg, M., Materechera, S., Kiba, D. I., Tamene, L., Ragnarsdóttir, K. V., Jongschaap, R., Hoogmoed, M., Hoogmoed, W., van Beek, C. and van Lynden, G. (2012) Assessing the impact of soil degradation on food production. *Current Opinion in Environmental Sustainability*. 4: 478-488.

Binns, T. (1995) *People and Environment in Africa.* John Wiley & Sons

Bizikova, L., Bellali, J., Habtezion, Z., Diakhite, M., and Pinter, L. (2009) IEA training manual volume 2: Vulnerability and impact assessments for climate change adaptation. Available at: http://www.iisd.org/pdf/2010/iea_training_vol_2_via.pdf. Accessed on17/02/2017.

BNRCC (2008) Building Nigeria’s response to climate change. Backgrounder, Nigerian Environmental Study Action Team, Ibadan, Nigeria

Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, (2007) Africa. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.

Bonnes, M., Lee, T., and Bonaiuto, M. (Eds.). (2003) Psychological theories for environmental issues. Burlington, VT: Ashgate Publishing Company.

Boserup, E. (1965) *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure.* Chicago: Aldine.124 pp.

Boyd, E., Cornforth, R. J., Lamb, P. J., Tarhule, A., Lele, M. I. and Brouder, A. (2013) Building resilience to face recurring environmental crisis in African Sahel. *Nature Clim. Change*. 3(7): 631-637

Brand, F. S., and K. Jax. (2007). Focusing the meaning(s) of resilience: resilience as a descriptive concept and a boundary object. *Ecology and Society* **12**(1): 23. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art23/

Brannen, J. (2008) The Practice of a Mixed Methods Research Strategy: Personal, Professional and Project Considerations. **In,** Bergman, M. M. (eds). *Advances in mixed methods research: Theories and applications*. London SAGE: 53-65

Briske, D. D., Illius, A. W. and Anderies, J. M. (2017) Nonequilibrium Ecology and Resilience Theory. **In**, Briske, D. D. (ed.) *Rangeland Systems: Processes, Management and Challenges.* Springer International Publishing: 197-227

Brklacich,M., Bryant, C., Veenhof, B. and Beauchesne, A. (2000) 'Agricultural adaptation to climatic change: A comparative assessment of two types of farming in central Canada', in H. Millward, K. Beesley, B. Ilbery and L. Harrington (eds.), *Agricultural and Environmental Sustainability in the New Countryside*, Winnipeg, Hignell Printing Limited, pp. 40–51.

Brockington, J. D., Harris, I. M. and Brook, R. M. (2016) Beyond the project cycle: a medium-term evaluation of agroforestry adoption and diffusion in a south Indian village. *Agroforestry Systems*. 90(3): 489-508

Bryan, E., Deressa, T. T., Gbetibouo, G. A. and Ringler, C. (2009) Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science & Policy*. 12(4): 413-426

Bryant, C. R., Smit, B., Brklacich, M., Johnston, T., Smithers, J., Chiotti, Q. and Singh, B. (2000) 'Adaptation in Canadian agriculture to climatic variability and change', *Clim. Change.* 45: 181–201.

Bryman, A. (2012) *Social Research Methods.* Fourth edn. Oxford University Press

Burbi, S., Baines, R. N. and Conway, J. S. (2013) Small-scale farmers and climate change-Opportunities and barriers to community engagement. *Aspects of Applied Biology*. 121: 213-218.

Burbi, S., Baines, R. N. and Conway, J. S. (2016) Achieving successful farmer engagement on greenhouse gas emission mitigation. *International Journal of Agricultural Sustainability*. 1-18

Burch, S. and Robinson, J. (2007) A framework for explaining the links between capacity and action in response to global climate change. *Climate Policy*. 7(4): 304-316

Burney, J., Cesano, D., Russell, J., La Rovere, E. L., Corral, T., Coelho, N. S. and Santos, L. (2014) Climate change adaptation strategies for smallholder farmers in the Brazilian Sertao. *Climatic Change*. 126(1-2): 45-59

Burpee, G., Brendan, S. J. and Schmidt, A. (2015) *Preparing smallholder farm families to adapt to climate change: Pocket Guide 3; Managing water resources.* Catholic Relief Services: Baltimore, MD, USA

Cameron, R. (2011) “Mixed Methods Research: The Five Ps Framework” *The Electronic Journal of Business Research Methods.* 9(2): 96-108

Carolan, M. (2013) *Reclaiming food security.* Routledge. London (Earthscan food and agriculture).

Carpenter, S., Walker, B., Anderies, J. M. and Abel, N. (2001) From Metaphor to Measurement: Resilience of What to What? *Ecosystems*. 4(8): 765–781

Carson, R. (1962) *Silent spring.* Penguin

Cash, D., Clark, W.C., Alcock, F., Dickson, N., Eckley, N., Ja¨ger, J. (2002). Salience, Credibility, Legitimacy and Boundaries: Linking Research, Assessment and Decision Making. KSG Working Papers Series RWP02-046. Available at SSRN: http://ssrn.com/abstract=372280 or doi:10.2139/ssrn.372280.

Catell, R. B. (1966). The scree test for number of factors. *Multivariate Behavioral Research*. 1: 245-276

CBN (2017) Central Bank of Nigeria Statistical Data base: Available at: http://statistics.cbn.gov.ng/cbn-onlinestats/QueryResultWizard.aspx. Generated on 22/01/2017.

Cerf, M., Gibbon, D., Hubert, B., Ison, R., Jiggins, J., Paine, M., Proost, J. and Röling, N. (2000) eds. *Knowing and learning for change in agriculture: case studies from industrialised countries*. Paris L’institut National de la Recherche Agronomic (INRA) Editions.

Cervigni, R., and Morris, M., editors. (2016) *Confronting Drought in Africa’s Drylands: Opportunities for Enhancing Resilience.* Africa Development Forum series. Washington, DC: World Bank. Doi: 10.1596/978-1-4648-0817-3.

Chambers, R. (1983) *Rural Development: Putting the Last First.* Addison Wesley Longman Limited

Chambers, R. (1994) *Paradigm Shifts and the Practice of Participatory Research and Development.* Institute of Development Studies

Chambers, R., Pacey, A. and Thrupp, L. (eds) (1989) *Farmer First: Farmer Innovation and Agricultural Research*. Intermediate Technology Publications, London.

Chu, H.-C. and Hwang, G.-J. (2008) A Delphi-based approach to developing expert systems with the cooperation of multiple experts. *Expert Systems with Applications*. 34(4): 2826-2840

Cline, W. R. (2007) *Global Warming and Agriculture: Impact Estimates by Country.* Center for Global Development, Washington, USA

Cline, W. R. (2008) Global Warming and Agriculture. *Finance & Development*. Available at: http://www.imf.org/external/pubs/ft/fandd/2008/03/pdf/cline.pdf. Accessed on: 26/01/2017.

Combs, J. P. and Onwuegbuzie, A. J. (2010) Describing and Illustrating Data Analysis in Mixed research. *International Journal of Education. 2(2) E13.*

Conner, M. and Sparks, P. (1996) The theory of planned behaviour and health behaviours. **In,** Conner, M. and Norman, P. (eds.) *Predicting Health Behaviour: Research and Practice with Social Cognition Models.* Open University Press. Buckingham, England. 121-162.

Conner, M., and Armitage, C. J. (1998) Extending the theory of planned behavior: A review and avenues for further research. *Journal of Applied Social Psychology*, 28(15), 1429-1464.

Cooke, B. and Kothari, U. (eds.) (2001) *Participation: The new tyranny.* Zed Books

Coppock, D. L. (2016) Pastoral System Dynamics and Environmental Change on Ethiopia's North-Central Borana Plateau-Influences of Livestock Development and Policy. **In**, Behnke, R. H. and Mortimore, M. (eds.) *The End of Desertification? Disputing Environmental Change in the Drylands.* Springer: 327-362.

Corbeels, M., de Graaff, J., Ndah, T. H., Penot, E., Baudron, F., Naudin, K., Andrieu, N., Chirat, G., Schuler, J., Nyagumbo, I., Rusinamhodzi, L., Traore, K., Mzoba, H. D. and Adolwa, I. S. (2014) Understanding the impact and adoption of conservation agriculture in Africa: A multi-scale analysis. *Agriculture, Ecosystems & Environment*. 187: 155-170

Cowie, A. L., Penman, T. D., Gorissen, L., Winslow, M. D., Lehmann, J., Tyrrell, T. D., Twomlow, S., Wilkes, A., Lal, R., Jones, J. W., Paulsch, A., Kellner, K. and Akhtar-Schuster, M. (2011) Towards Sustainable Land Management in the Drylands: Scientific Connections in Monitoring and Assessing Dryland Degradation, Climate Change and Biodiversity. *Land Degradation and Development*. 22: 248-260.

Crang, M. and Cook, I. (1995) 'Doing ethnographies.' Norwich: Geobooks.

Craswell, E.T and Vlek, P.L.G. (2013) Mining of Nutrients in African Soils Due to Agricultural Intensification. **In,** Lal, R. and Stewart B.A. (eds.) *Principles of Sustainable Soil Management in Agroecosysems.* Taylor & Francis Group: 401-422.

Creswell, J. W. (2013) *Qualitative inquiry & research design: choosing among five approaches.* 3rd edn. SAGE

Creswell, J.W., Plano Clark, V.L and Garreth, A.L. (2008) Methodological Issues in conducting Mixed Methods Research Design. **In,** Bergman, M. M. (eds). *Advances in mixed methods research: Theories and applications*. London SAGE: 66-83

Dang, H. L., Li, E., Bruwer, J. and Nuberg, I. (2014a) Farmers' perceptions of climate variability and barriers to adaptation: lessons learned from an exploratory study in Vietnam. *Mitigation and Adaptation Strategies for Global Change*. 19(5): 531-548

Dang, H. L., Li, E., Nuberg, I. and Bruwer, J. (2014b) Understanding farmers' adaptation intention to climate change: A structural equation modelling study in the Mekong Delta, Vietnam. *Environmental Science & Policy*. 41: 11-22

Danjuma, M. N., Mohammed, S. and Daura, U. S. (2014) Mitigation Strategies to Environmental Degradation in Nigeria. *Journal of Environment and Earth Science*. 4(21).
Darkoh, M. B. K. (2003) Regional perspectives on agriculture and biodiversity in the drylands of Africa. *Journal of Arid Environments*. 54(2): 261-279.

Darnhofer, I., Fairweather, J. and Moller, H. (2010) Assessing a farm's sustainability: insights from resilience thinking. *International Journal of Agricultural Sustainability*. 8(3): 186-198

Davidson, D. J. (2010) The Applicability of the Concept of Resilience to Social systems: Some Sources of Optimism and Nagging Doubts. *Society & Natural Resources*. 23(12): 1135-1149

Davies, A. E. (2009) Food Security Initiatives in Nigeria: Prospects and Challenges. *Journal of Sustainable Development in Africa*. 11(1): 186-202

Davis, K. E. (2008) Extension in Sub-Saharan Africa: Overview and Assessment of Past and Current Models, and Future Prospects. *J. Int. Agric. Ext. Edu.* 15(3).

Dawoe, E. K., Quashie-Sam, J., Isaac, M. E. and Oppong, S. K. (2012) Exploring farmers' local knowledge and perceptions of soil fertility and management in the Ashanti Region of Ghana. *Geoderma*. 179: 96-103

Dawson, C. (2009) *Introduction to Research Methods: A practical guide for anyone undertaking a research project.* Fourth edn. How To Books Ltd

de Fraiture, C. Karlberg, L. and Rockström, J.(2009) Can rainfed Agriculture Feed the World? An Assessment of Potentials and Risk. **In**, S.P Wani, J. Rockström and T Oweis (eds.) *Rainfed Agriculture: Unlocking the Potential.* CAB International: 124-132

De Haen, H. (1997) Environmental Consequences of Agricultural Growth in Developing Countries. **In**, Vosti, S. A. and Reardon, T. (eds.) *Sustainability, Growth, and Poverty Alleviation: A Policy and Agroecological Perspective.*

Delgado, J. A. and Bausch, W. C. (2005) Potential use of precision conservation techniques to reduce nitrate leaching in irrigated crops. *Journal of Soil Water Conservation.* 60: 379-387

Denscombe, M. (2014) *The Good Research Guide For small-scale social research projects.* 5th edn. Open University Press

Deressa, T. T., Hassan, R. M., and Ringler, C. (2011) Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *Journal of Agricultural Science. 149*: 23-31. http://dx.doi.org/10.1017/S0021859610000687

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T. and Yesuf, M. (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*. 19(2): 248-255

De Schutter, O. (2013) *Gender Equality and Food Security: Women's Empowerment as a Tool against Hunger*. Asian Development Bank and Food and Agriculture Organisation. Available from: http://www.fao.org/wairdocs/ar259e/ar259e.pdf

DeVellis, R. F. (2012) *Scale Development: Theory and Applications* (3rd edn). Thousand Oaks, California: Sage.

de Vente, J., Reed, M. S., Stringer, L. C., Valente, S. and Newig, J. (2016) How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands. *Ecology and Society*. 21(2)

Devereux, S. (2001) Livelihood Insecurity and Social Protection: A Re-emerging Issue in Rural Development. *Development Policy Review*. 19(4): 507-519.

Dile, Y. T., Karlberg, L., Temesgen, M., and Rockström, J. (2013) The role of water harvesting to achieve sustainable agricultural intensification and resilience against water related shocks in sub-Saharan Africa. *Agriculture, ecosystems & environment*. *181*: 69-79.

Dillman, D. A. (1991) The Design and Administration of Mail Surveys. *Annual Review of Sociology*. 17(1): 225-249

Dixon, J., Gulliver, A. and Gibbon, D. (2001) *Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World*. FAO and World Bank. Available from: http://www.fao.org/3/a-ac349e.pdf

Donye, A. O. and Ani, A. O. (2014) Policy issues on agricultural extension practices and the transformation of adult-farmer education in Nigeria. *American Journal of Social and Management Sciences*, 5 (1);11-18.

Dougill, A. J., David, S. G. T. and Heathwaite, A. L. (1999) Environmental Change in the Kalahari: Integrated Land Degradation Studies for Nonequilibrium Dryland Environments. *Annals of the Association of American Geographers*. 89(3): 420-442

Downing, T. E. and Parry, M. L. (1997) Global Climate Change: Implications for the Links between Sustainability, Growth, and Poverty Alleviation. **In**, Vosti, S. A. and Reardon, T.

(eds.) *Sustainability, Growth, and Poverty Alleviation: A Policy and Agroecological Perspective.* The Johns Hopkins University Press: 90-102.

Dupraz, C. L. and Postolle, A. (2013) Food sovereignty and agricultural trade policy commitments: How much leeway do West African nations have? *Food Policy.* 38: 115–125.

D'Odorico, P., Bhattachan, A., Davis, K. F., Ravi, S. and Runyan, C. W. (2013) Global desertification: Drivers and feedbacks. *Advances in Water Resources*. 51: 326-344.

Eagly, A. H. and Chaiken, S. (1998) Attitude structure and function. **In,** Gilbert, D.T. Fiske, S.T. (eds.) *The Handbook of Social Psychology.* McGraw-Hill. Boston. 4th edn.

Eicher, C.K., (2003) 'Flashback: fifty years of donor aid to African agriculture', Successes in African Agriculture Conference Paper 16, Washington, D.C.: International Food Policy Research Institute

Eklundh, L. and Olsson, L. (2003) Vegetation index trends for the African Sahel 1982–1999. *Geophysical Research Letters*. 30(8)

Ellis, F. (1993) Peasant Economics: Farm Households and Agrarian Development, Second ed. Cambridge University Press, Cambridge.

Ellis, F. (2000) Rural Livelihoods and Diversity in Developing Countries. Oxford University Press, Oxford.

Ellis, F., Allison, E. H. (2005) Livelihood diversification and natural resource access. Working Paper No. 9, Livelihood Support Programme, Rome, FAO.

Ellis, J. E. (1995) Climate variability and complex ecosystem dynamics: implications for pastoral development. Pages 37-46 *in* I. Scoones, editor. *Living with uncertainty: new directions in pastoral development in Africa.* International Institute for Environment and Development, London, UK.

Ellis, J. E., and Swift, D. M. (1988) Stability of African pastoral ecosystems: Alternate Paradigms and Implications for Development. *Journal of Range Management.* 41:450-59.

Eshuis, J., and Stuiver, M. (2005) Learning in context through conflict and alignment: farmers and scientist in search of sustainable agriculture. *Agriculture and Human Values.* 22(2): 137-148.

Fabiyi, O. O. and Oloukoi, J. (2013) Indigenous Knowledge System and Local Adaptation Strategies to Flooding in Coastal Rural Communities of Nigeria. *Journal of Indigenous Social Development*. 2(1): 1-19.

Fairhead, J. and Scoones, I. (2005) Local knowledge and the social shaping of soil investments: critical perspectives on the assessment of soil degradation in Africa. *Land Use Policy*. 22: 33-41.

Falkenmark, M. and Rockström, J. (2008) Building resilience to drought in desertification-prone savannas in Sub-Saharan Africa: The water perspective. *Natural Resources Forum*. 32(2): 93-102

FAO. (1993) *Agricultural extension and farm women in the 1980s*. Food and Agriculture Organization of The United Nations

FAO. (1997) Improving Soil fertility in Africa. FAO soils Bulletin 14, Rome.

FAO. (1996) *Technology Assessment and Transfer Towards Food Security and Poverty Alleviation in Sub-Saharan Africa*, Food and Agricultural Organisation, Rome.

FAO. (2003) Report of the FAO Expert Consultation on a Good Agricultural Practice approach. Rome, Italy, 10-12. FAO GAP WORKING PAPER SERIES 1. Available at: http://www.fao.org/search/en/?cx=018170620143701104933%3Aqq82jsfba7w&q=GAP+working+paper+series&cof=FORID%3A9&siteurl=www.fao.org%2Fabout%2Fen%2F&ref=www.fao.org%2Fpublications%2Fsofi%2F2014%2Fen%2F&ss=9951j10542305j25. [Accessed on 11/05/15].

FAO. (2004) Carbon sequestration in dryland soils. World Soil Resources Report 102. FAO-Rome.

FAO. (2006) Food security. Policy brief, Issue 2, June 2006. Rome.

FAO. (2008) *The State of Food Insecurity in the World 2008: High food prices and food security – threats and opportunities*, Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. (2009) *Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies.* [online] FAO. Available from: http://www.fao.org/docrep/012/i1318e/i1318e00.pdf [Date accessed: 14/10/2016]

FAO. (2011) The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London.

FAO. (2012) *The State of Food and Agriculture.* [online] FAO. Available from: http://www.fao.org/docrep/017/i3028e/i3028e.pdf [Date accessed: 22/04/2017]

FAO. (2013) Climate-smart agriculture sourcebook. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).

FAO. (2015a) *Food Outlook 2015*. Food and Agricultural Organization of the United Nations.

FAO. (2015b) *The State of Food and Agriculture: Social protection and agriculture: breaking the cycle of rural poverty*. Food and Agriculture Organization of the United Nations

FAO. (2016a) *Farmer Field School Guidance Document: Planning for quality programmes.* Food and Agricultural Organization of the United Nations, Rome

FAO. (2016b) *The State of Food and Agriculture: Climate Change, Agriculture and Food Security*. Food and Agriculture Organization of the United Nations.

FAO. (2017a) *The future of Food and Agriculture: Trends and Challenges | FAO | Food and Agriculture Organization of the United Nations.* [online] FAO. Available from: http://www.fao.org/about/meetings/council/cl155/cl155-side-events/future-food-trends-challenges/en/ [Date accessed: 27/02/2017]

FAO. (2017b) *FAO - News Article: FAO Director-General urges more support to help small farmers adapt to a changing climate.* [online] FAO. Available from: http://www.fao.org/news/story/en/item/470338/icode/?utm_content=bufferdf5c9&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer [Date accessed: 15/02/2017]

Fazey, I., Evely, A. C., Reed, M. S., Stringer, L. C., Kruijsen, J., White, P. C. L., Newsham, A., Jin, L., Cortazzi, M., Phillipson, J., Blackstock, K., Entwistle, N., Sheate, W., Armstrong, F., Blackmore, C., Fazey, J., Ingram, J., Gregson, J. O. N., Lowe, P., Morton, S. and Trevitt, C. (2013) Knowledge exchange: a review and research agenda for environmental management. *Environmental Conservation*. 40(1): 19-36

Federal Ministry of Environment Climate Change Department (2011) *National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN)* (online). Available from: http://nigeriaclimatechange.org/docs/naspaAug2012.pdf. Accessed on: 17/10/2015.

Finch, H., Lewis, J. and Turley, C. (2014) Focus Groups. **In,** Ritchie, J., Lewis J., Nicholls C.M. and Ormston R. (ed.) (2014) *Qualitative research practice; a guide for social science students and researchers.* 2nd edn. London SAGE Publications Ltd. 211-242

Fishbein, M., Ajzen, I. (2010) *Predicting and changing behavior: The reasoned action approach*. New York: Psychology Press.

Fisher, C. (2010) *Researching and writing a dissertation: An essential guide for business students.* Third edn. Pearson Education Limited

Fisher, R. K (2012) The Role of Social Capital in Influencing Capacity of Farmers to Bovine Tuberculosis. PhD thesis submitted to the University of Gloucestershire (Unpublished)

Fixen, P., Brentrup, F., Bruulsema, T.W., Garcia, F., Norton, R. and Zingore, S. (2015) Nutrient/fertilizer use efficiency: measurement, current situation and trends. ***In:*** P. Dreschler, Heffer, P., Magen, H., Mikkelsen, R. and Wichelns, D. (2015) *Managing water and fertilizer* *for sustainable agricultural intensification*. Paris, International Fertilizer Industry Association (IFA), International Water Management Institute (IWMI), International Plant Nutrition Institute (IPNI), and International Potash Institute (IPI).

Flaherty, K., Ayoola, G., Ogbodo, J. and Beintema, N. (2010) *Nigeria: Recent Developments in Agricultural Research.* [online] International Food Policy Research Institute. Available from: https://www.asti.cgiar.org/pdf/Nigeria-Note.pdf [Date accessed: 22/05/2017]

Flemig, S., Osborne, S. and Kinder, T. (2014) *Risk Definition and Risk Governance in Social Innovation Processes: A conceptual Framework.*

FMARD (Federal Ministry of Agriculture and Rural Development) (2013). *National Agricultural Resilience Framework (NARF): A report by the Advisory Committee on Agricultural Resilience in Nigeria (ACARN)*. Nigerian Government.

FMARD (Federal Ministry of Agriculture and Rural Development) (2016). *The Agriculture Promotion Policy (2016-2020): Building on the Successes of the ATA, Closing Key Gaps*

Folke, C. (2006) Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*. 16(3): 253-267

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T. and Rockström, J. (2010) Resilience Thinking: Integrating Resilience, Adaptability and Transformability. *Ecology & Society*. 15(4): 1-9

Foresight, (2011) The Future of Food and Farming: Challenges and choices for global sustainability. The Government Office for Science, London.

Fosu-Mensah, B. Y., Vlek, P. L. G. and MacCarthy, D. S. (2012) Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability*. 14(4): 495-505

Francis C., Lieblein G., Gliessman S., Breland T. A., Creamer N., Harwood R., Salomonsson L., Helenius J., Rickerl D., Salvador R., Wiedenhoeft M., Simmons S., Allen P., Altieri M., Flora C. & Poincelot R. (2003) Agroecology: The Ecology of Food Systems. *Journal of Sustainable Agriculture*. 22(3): 99-118. DOI: 10.1300/J064v22n03_10

Frank, E., Eakin, H. and López-Carr, D. (2011) Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. *Global Environmental Change*. 21(1): 66-76

Frank, J. and Penrose Buckley, C. (2012) Small-scale farmers and climate change. How can farmer organisations and Fairtrade build the adaptive capacity of smallholders? IIED, London.

Fraser, E. D. G., A. J. Dougill, K. Hubacek, C. H. Quinn, J. Sendzimir, and M. Termansen. (2011) Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions. *Ecology and Society.* 16(3): 3.

Freshwater, D. (2015) Vulnerability and Resilience: Two Dimensions of Rurality. *Sociologia Ruralis*. 55(4): 497-515

FRN (Federal Republic of Nigeria). (2012) Great Green Wall for The Sahara and Sahel Initiative National Strategic Action Plan.

Fuglie, K. O. and Kascak, C. A. (2001) Adoption and Diffusion of Natural-Resource-Conserving Agricultural Technology. *Review of Agricultural Economics*. 23(2): 386-403

Gabriel, U. U., Akinrotimi, O. A., Bekibele, D. O., Anyanwu, P. E. and Onunkwo, D. N. (2007) Economic benefit and ecological efficiency of integrated fish farming in Nigeria. *Scientific Research and Essay.* 2(8): 302-308.

Gallopín, G. C. (2006) Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change*. 16(3): 293-303

Garb, Y. and Friedlander, L. (2014) From transfer to translation: using systemic understandings of technology to understand drip irrigation uptake. *Agric Syst.* 128:13-24

Giannini, A. (2016) 40 Years of Climate Modeling: The Causes of Late 20th Century Drought in the Sahel. **In**, Behnke, R. H. and Mortimore, M. (eds.) *The End of Desertification? Disputing Environmental Change in the Drylands.* Springer: 265-292.

Gilham, B. (2000) *Case study research methods.* Continuum Press

Giller, K. E., Witter, E., Corbeels, M. and Tittonell, P. (2009) Conservation agriculture and smallholder farming in Africa: The heretics' view. *Field Crops Research*. 114(1): 23-34

Gitz, V. and Meybeck, A. (2012) Risks, vulnerabilities and resilience in a context of climate change. FAO/OECD Workshop: Building Resilience for Adaptation to Climate Change in the Agricultural Sector, Rome, Italy, 23–24 April (2012) Available at: http://www.fao.org/docrep/017/i3084e/i3084e03.pdf. Accessed on 16/10/16.

Gliessman, S. R. (2005) Agroecology and Agroecosystems. **In,** Pretty, J. N. (Ed.) The Earthscan Reader in Sustainable Agriculture. London, Earthscan.

Gliessman, S. (2013) Agroecology: Growing the Roots of Resistance, *Agroecology and Sustainable Food Systems.* 37(1): 19-31

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., & Toulmin C. (2010) Food Security: The Challenge of Feeding 9 Billion People. *Science* 327: 812-818.

Gordon, T. J. (1994) *The Delphi method. Futures research methodology*. Available from: http://fpf.ueh.edu.vn/imgnews/04-Delphi.pdf

Gowing, J. W. and Palmer, M. (2008) Sustainable agricultural development in sub-Saharan Africa: the case for a paradigm shift in land husbandry. *Soil Use and Management*. 24(1): 92-99

Granatstein, D. (1992) Dryland Farming in the Northwestern United States: A Nontechnical Overview. MISC0162, Washington State University Cooperative Extension, Pullman. 31 pp

Graves, A., Matthews, R. and Waldie, K. (2004) Low External Input Technologies for Livelihood Improvement in Subsistence Agriculture. **In**, *Advances in Agronomy.* Vol. Volume 82. Academic Press: 473-555

Greiner, R. and Gregg, D. (2011) Farmers' intrinsic motivations, barriers to the adoption of conservation practices and effectiveness of policy instruments. Empirical evidence from northern Australia. *Land Use Policy.* 28(1): 257-265 doi:10.1016/j.landusepol.2010.06.006

Grothmann, T. and Patt, A. (2005) Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change*. 15(3): 199-213

Grundy, M. and Ghazi, F. (2009) Research priorities in haemato-oncology nursing: Results of a literature review and a Delphi study. *European Journal of Oncology Nursing*. 13: 235-249

Gunderson, L, Holling, C. S, (eds.) (2001) Panarchy: understanding transformations in human and natural systems. Washington (DC): Island Press.

Hanjra, M. A and Qureshi, M. E (2010) Global water crisis and future food security in an era of climate change. *Food Policy* (35) 365–377

Hardaker, J. B., Huirne, R. B. M., Anderson, J. R. and Lien, G. (2004) *Coping with Risk in Agriculture.* Second edn. CAB International

Hardaker, J. B., Lien, G., Anderson, J. R. and Huirne, R. B. M. (2015) *Coping with Risk in Agriculture: applied decision analysis.* 3rd edn. CAB International

Hardin, G. (1968) The tragedy of the Commons. *Science*. 162: 1243-1248

Harris, F. (1999) Nutrient Management Strategies of Small-Holder Farmers in a Short-Fallow Farming System in North-East Nigeria. *The Geographical Journal*. 165(3): 275-285

Hasson, F., Keeney, S. and McKenna, H. (2000) Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing*. 32(4): 1008-1015

Haug, R. (2000) *Agricultural Extension- The power of Knowledge in Process of Change: Lessons Learned and Future Challenges for Africa.* [online] Available from: http://www.umb.no/statisk/noragric/publications/scinews/2000_scinews_04.pdf [Date accessed: 16/05/2017]

Helldén, U. and Tottrup, C. (2008) Regional desertification: A global synthesis. *Global and Planetary Change*. 64(3–4): 169-176

Hellmuth, M., Moorhead, A., Thomson, M. C. and Williams, J. (eds.) (2007) *Climate Risk Management in Africa: Learning from Practice.* International Research Institute for Climate and Society (IRI), Columbia University.

Herrmann, S. M. and Hutchinson, C. F. (2005) The changing contexts of the desertification debate. *Journal of Arid Environments*. 63(3): 538-555.

Herrmann, S. M., Anyamba, A. and Tucker, C. J. (2005) Recent trends in vegetation dynamics in the African Sahel and their relationship to climate. *Global Environmental Change*. 15(4): 394-404

Hisali, E., Birungi, P. and Buyinza, F. (2011) Adaptation to climate change in Uganda: Evidence from micro level data. *Global Environmental Change*. 21(4): 1245-1261

Holling, C. S. (1973) Resilience and stability of ecological systems. *Annu. Rev. Ecol. Syst.*

4:1–21

Holmen, H. (2011) The Millennium Goals, the State and Macro-level Performance: an Overview. **In**, Djurfeldt, G., Aryeetey, E. and Isinika, A. C. (eds.) *African Smallholders: Food Crops, Markets, and Policy.* CAB International: 45-73.

Holmen, H. and Hyden, G. (2011) African Agriculture: from Crisis to Development. **In**, Djurfeldt, G., Aryeetey, E. and Isinika, A. C. (eds.) *African Smallholders: Food Crops, Markets, and Policy.* CAB International: 23-44

Horlings, L. G. and Marsden, T. K. (2011) Towards the real green revolution? Exploring the conceptual dimensions of a new ecological modernisation of agriculture that could 'feed the world'. *Global Environmental Change*. 21(2): 441-452

Hsu, C.-C. and Sandford, B. A. (2007) The Delphi Technique: Making Sense of Consensus. *Practical Assessment, Research & Evaluation*. 12(10): 1-8

Hulme, M. (2001) Climatic perspectives on Sahelian desiccation: 1973–1998. *Global Environmental Change*. 11(1): 19-29.

Huq, S. and Ayers, J. (2007) Critical list: the 100 nations most vulnerable to climate change. Sustainable Development Opinion, International Institute for Environment and Development (IIED), London

Hutchinson, C. F. and Herrmann, S. M. (2008) *The Future of Arid Lands-Revisited: A Review of 50 Years of Drylands Research*. Springer, Paris.

ICARDA. (2015) *Adapting to Climate Change.* [online] Available from: http://www.icarda.org/global-research-themes/adapting-climate-change [Date accessed: 02/06/2015]

Idachaba, F. S. (1980) Agricultural research policy in Nigeria. International Food Policy Research Institute (IFPRI) Research Report 17. **ISBN 0-89629-018.2.**

IFAD. (2009) *Nigeria: Country Programme Evaluation*. International Fund for Agricultural Development.

IFAD. (2011) Proceedings, IFAD (International Fund for Agricultural Development) Conference on New Directions for Smallholder Agriculture, 24-25 January 2011. IFAD, WFP, and FAO, 2012: The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, pp. 61.

Ikpi, A. (1995) Policy relevance of research for sustainable development in Nigeria's agriculture. **In**, Ikpi, A. E. & Olayemi, J. K. (Eds.) *Sustainable Agriculture and Economic Development in Nigeria.* Winrock International, Institute for Agricultural Development publication, Ibadan.

ILRI. **(**2006) Pastoralist and Poverty Reduction in East Africa's Conference, June 2006. International Livestock Research Institute (ILRI), Nairobi Kenya

IBRD & WB (International Bank for Reconstruction and Development & World Bank). (2015). World Development Indicators 2015. Washington, DC: IBRD/The World Bank.

Ingram, J. (2008) Agronomist-farmer knowledge encounters: an analysis of knowledge exchange in the context of best management practices in England. *Agriculture and Human Values*. 25(3): 405-418

IPCC. (2007) *Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change, impacts, adaptation and vulnerability, Climate change 2007.* Cambridge University Press

IPCC. (2012) Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA. 1-19.

Irohibe I. J. and Agwu A. E. (2014) Assessment of Food Security Situation among Farming Households in Rural Areas of Kano State, Nigeria. *Journal of Central European Agriculture*. 15(1): 94-107.

Islam, M. M., Barnes, A., and Toma, L. (2013) An investigation into climate change scepticism among farmers. *Journal of Environmental Psychology.* 34(0): 137-150.

IUCN. (2015) *IUCN - Sustainable Dryland Landscapes in Africa and the Middle East.* [online] Available from: http://iucn.org/about/work/programmes/ecosystem_management/about_work_global_prog_ecos_dry/iucns_work_in_the_drylands_/sustainable_dryland_landscapes_in_africa_and_the_middle_east/ [Date accessed-04/05/2015].

IWMI (International Water Management Institute). (2007) *Water for food Water for life: A Comprehensive Assessment of Water Management in Agriculture.* Earthscan

Iwuchukwu, J. C. and Igbokwe, E. M. (2012) Lessons from Agricultural Policies and Programmes in Nigeria. *Journal of Law, Policy and Globalization*. 5: 11-21.

Jalloh, A., Faye, M. D., Roy-Macauley, H., Sereme, P., Zougmore, R., Thomas, T. S. and Nelson, G. C. (2013) Overview. **In**, Jalloh, A., Nelson, G. C., Thomas, T. S., *et al.* (eds.) *West African Agriculture and Climate Change: A comprehensive analysis.* 1st edn. International Food Policy Research Institute: 1-35

Jantarasami, L. C., Lawler, J. J. and Thomas, C.W. (2010) Institutional barriers to climate change adaptation in US national parks and forests. *Ecology and Society.* 15(4): 33.

Jayne, T.S., Govereh, J., Mwanaumo, A., Chapoto, A. and Nyoro, J.K., (2002) False promise of false premise? The experience of food and input market reforming Eastern and Southern Africa. *World Development*. 30 (11): 1967–85

Jerneck, A. and Olsson, L. (2008) Adaptation and the poor: development, resilience and transition. *Climate Policy (Earthscan)*. 8(2): 170-182

Jiang, H. (2016) Taking Down the "Great Green Wall": The Science and Policy Discourse of Desertification and Its Control in China. **In**, Behnke, R. H. and Mortimore, M. (eds.) *The End of Desertification? Disputing Environmental Change in the Drylands.* Springer: 513-536

Johansen, C., Haque, M. E., Bell, R. W., Thierfelder, C. and Esdaile, R. J. (2012) Conservation agriculture for small holder rainfed farming: Opportunities and constraints of new mechanized seeding systems. *Field Crops Research*. 132: 18-32.

Johnson, R. and Onwuegbuzie A. (2004) Mixed Methods Research: A Paradigm Whose Time Has Come. *Educational Researcher*. 33 (7): 14-26

Johnson, R., Onwuegbuzie, A. and Turner, L. (2007) Toward a definition of mixed methods research. *Journal of Mixed Methods Research.* 1(2): 112-133

Joliffe, I. T. (2002) *Principal component analysis.* Springer

Jones, L. and Boyd, E. (2011) Exploring social barriers to adaptation: Insights from Western Nepal. Global Environmental Change. 21(4): 1262-1274

Jones, L., Carabine, E., Hickman, A., Langston, L., Moosa, S. and Mukanya, R. (2014). *Exploring the role of climate science in supporting long-term adaptation and decision-making in sub-Saharan Africa*

Juma, C. (2015) *The New Harvest: Agricultural Innovation in Africa.* Second edn. Oxford University Press

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L. and Schösler, H. (2016) Transition towards Circular Economy in the Food System. *Sustainability*. 8(1)

Kaiser, H. (1970) A second generation Little Jiffy. *Psychometrika*. 35: 401-415

Kaiser, H. (1974) An index of factorial simplicity. *Psychometrika*. 39: 31-36

Kang, Y., Khan, S., and Ma, X. (2009) Climate change impacts on crop yield, crop water productivity and food security– A review. *Progress in Natural Science*. 19:1665–1674.

Kaye-Zwiebel, E. and King, E. (2014) Kenyan pastoralist societies in transition: varying perceptions of the value of ecosystem services. *Ecology and Society*. 19(3): 17

Keeney, S., Hasson, F. and McKenna, H. P. (2001) A critical review of the Delphi technique as a research methodology for nursing. *International Journal of Nursing Studies*. 38(2): 195-200

Kiage, L. M. (2013) Perspectives on the assumed causes of land degradation in the rangelands of Sub-Saharan Africa. *Progress in Physical Geography*. 37(5): 664-684.

Kidane, G. (2010) *Agricultural based Livelihood Systems in Drylands in the Context of Climate Change: Inventory of Adaptation Practices and Technologies of Ethiopia*.

Kidane, G., Dejene, A. and Malo, M. (2010) *Agricultural based Livelihood Systems in Drylands in the Context of Climate Change: Inventory of Adaptation Practices and Technologies of Ethiopia.* FAO. Rome. Available at: http://www.fao.org/docrep/014/i1786e/i1786e00.pdf. Accessed on: 02/03/2017.

Kilpatrick, S. (2002) Facilitating sustainable natural resource management: review of the literature. Prepared for Department of Primary Industries, Water and Environment as part of the evaluation of the Implementation of Best Practice in Sustainable Agriculture project. University of Tasmania.

Knoop L., Sambalino F., and Van Steenbergen, F. (2012) Securing Water and Land in the Tana Basin: a resource book for water managers and practitioners. Wageningen, The Netherlands: 3R Water Secretariat.

Knowler, D. and Bradshaw, B. (2007) farmers' adoption of conservation agriculture: a review and synthesis of recent research. *Food Policy.* 32:25-48

Kolawole, O.D. (2013) Soils, science and the politics of knowledge: How African smallholder farmers are framed and situated in the global debates on integrated soil fertility management. *Land Use Policy*. 30: 470– 484.

Koontz, T. M., Garrett, V., Martin, R., Marquis, C., Mudliar, P., Ritter, T. and Zwickle, S. (2013) Human Dimensions That Drive Soil Degradation. **In,** Lal, R. and Stewart B.A. (eds.) *Principles of Sustainable Soil Management in Agroecosysems.* Taylor & Francis Group: 167-188.

Kothari, U. (2001) Power, Knowledge and Social Control in Participatory Development. **In**, Cooke, B. and Kothari, U. (eds.) *Participation: The New Tyranny?* Zed Books: 139-152

Koyenikan, M. J. (2008) Issues for Agricultural Extension Policy in Nigeria. *Journal of Agricultural Extension*. 12(2): 52-62

Kpadonou, R. A. B., Owiyo, T., Barbier, B., Denton, F., Rutabingwa, F. and Kiema, A. (2017) Advancing climate-smart-agriculture in developing drylands: Joint analysis of the adoption of multiple on-farm soil and water conservation technologies in West African Sahel. *Land Use Policy*. 61: 196-207

Kuhnert, P. M., Martin, T. G. and Griffiths, S. P. (2010) A guide to eliciting and using expert knowledge in Bayesian ecological models. *Ecology Letters*. 13: 900-914

Kurukulasuriya, P. and Mendelsohn, R. (2008) A Ricardian Analysis of the Impact of Climate Change on African Cropland. *AfJARE.* 2(1): 1-23

Kuznets, S. (1955). Economic growth and income inequality. *American Economic Review*. 45: 67–98.

Ladan, M. T (2013) Agricultural Resources Policy and Law in Nigeria. Prof. Ladan's Law and Policy Review Research Working Papers. No. 7. Available at: file://filestore/students/10208020/Downloads/AGRICULTURAL_RESOURCES_POLICY_AND_LAW_IN.pdf. Accessed on 16/06/2017.

Lal, R. (1997) Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by CO2-enrichment. *Soil and Tillage Research*. 43(1): 81-107

Lal, R., (1999) Global carbon pools and fluxes and the impact of agricultural intensification and judicious land use. Prevention of Land Degradation, Enhancement of Carbon Sequestration and Conservation of Biodiversity through Land Use Change and Sustainable Land Management with a Focus on Latin America and the Caribbean. World Soil Resources Report 86. FAO, Rome, pp. 45– 52.

Lal, R. (2004) Soil carbon sequestration to mitigate climate change. *Geoderma*. 123(1): 1-22

Lal, R. (2013) Principles of Soil Management. **In,** Lal, R. and Stewart B.A. (eds.) *Principles of Sustainable Soil Management in Agroecosysems.* Taylor & Francis Group: 1-19

Lal, R., Negassa, W. and Lorenz, K. (2015) Carbon sequestration in soil. *Current Opinion in Environmental Sustainability*. 15: 79-86

Lambrecht, I., Vanlauwe, B. and Maertens, M. (2016) Integrated soil fertility management: from concept to practice in Eastern DR Congo. *International Journal of Agricultural Sustainability*. 14(1): 100-118

Lancaster, B. (2010) *Rainwater Harvesting for Drylands and Beyond.* (2). Rainsource Press

Landeta, J. (2006) Current validity of the Delphi method in social sciences. *Technological Forecasting and Social Change*. 73(5): 467-482

Lane, A. and Jarvis, A. (2007) Changes in climate will modify the geography of crop suitability: Agricultural biodiversity can help with adaptation. *Journal of the Semi-Arid Tropical Agricultural Research*. 4(1): 1-12

Larson, D. F. and Otsuka, K. (2016) Introduction: Why an African Green Revolution Is Needed and Why It Must Include Small Farms. **In**, *In Pursuit of an African Green Revolution.* Springer, Washington, USA: 1-11

Leach, M. (2008) Re-framing Resilience: A Symposium Report, STEPS Working Paper 13, Brighton: IDS

Leeuwis, C. and van den Ban, A. **(**2004) Communication for rural innovation: rethinking agricultural extension. UK, Blackwell Science Ltd.

Levario, K. H. (2007) *Design for Water: Rainwater Harvesting, stormwater Catchment, and Alternate Water Reuse.* New Society Publishers

Lin, S. P. (2013) The gap between global issues and personal behaviors: pro-environmental behaviors of citizens toward climate change in Kaohsiung, Taiwan. *Mitigation and Adaptation Strategies for Global Change*. 18(6): 773-783

Linstone, H. A. and Turoff, M. (2002) Introduction. **In**, Linstone, H.A. and Turoff, M. (Eds.), The Delphi Method: Techniques and Applications (pp. 3 – 12). Newark: New Jersey Institute of Technology.

Lipper, L., Dutilly-Diane, C. and McCarthy, N. (2010) Supplying Carbon Sequestration from West African Rangelands: Opportunities and Barriers. *Rangeland Ecology & Management*. 63(1): 155-166

Lister, R. (2004) Poverty. Cambridge, Polity Press.

Little, P. D. (2013) Reflections on the future of pastoralism in the Horn of Africa. Pages 243-249 *in* A. Catley, J. Lind, and I. Scoones, editors. *Pastoralism and development in Africa: dynamic change at the margins.* Routledge, New York, New York, USA

Liverman, D. M. (2008) Conventions of CC: constructions of danger and dispossession of the atmosphere. *Journal of Historical Geography* **35**:279–296.

Long, T. B., Blok, V. and Coninx, I. (2015) Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from Netherlands, France, Switzerland and Italy. *Journal of Cleaner Production*. 1-13

Loos, J., Abson, D. J., Chappell, M. J., Hanspach, J., Mikulcak, F., Tichit, M. and Fischer, J. (2014) Putting meaning back into "sustainable intensification". *Frontiers in Ecology and the Environment*. 12(6): 356-361

Lozano, L. M., García-Cueto, E. and Muñiz, J. (2008) Effect of the Number of Response Categories on the Reliability and Validity of Rating Scales. *Methodology*. 4(2): 73-79

Luan, Y., Cui, X. and Ferrat, M. (2013) Historical trends of food self-sufficiency in Africa. *Food Security*. 5(3): 393-405

Luers, A. L. (2005) The surface of vulnerability: An analytical framework for examining environmental change. *Global Environmental Change*. 15(3): 214-223

Lybbert, T. J. and Sumner, D. A. (2012) Agricultural technologies for climate change in developing countries: Policy options for innovation and technology diffusion. *Food Policy*. 37(1): 114-123

MacKinnon, D. and Derickson, K. D. (2012) From resilience to resourcefulness: A critique of resilience policy and activism. *Progress in Human Geography*. 37(2): 253-270

Macnaghten, P. and Jacobs, M. (1997) Public identification with sustainable development. *Global Environmental Change*. 7(1): 5-24

Madden, T. J., Ellen, P. S., and Ajzen, I. (1992) A comparison of the theory of planned behavior and the theory of reasoned action. *Personality and Social Psychology Bulletin*. 18(1): 3-9.

Maddison, D. (2007) The perception of and adaptation to climate change in Africa. The World Bank Policy Research Working Paper 4308. Development Research Group. Available at: http://documents.worldbank.org/curated/en/479641468193774164/pdf/wps4308.pdf. Accessed on 02/04/2017.

Makhado R. A, Saidi A. T and Tshikhudo P. P. (2014) Optimising drought adaptation by smallscale farmers in southern Africa through integration of indigenous and technologically-driven practices. *African Journal of Science,Technology, Innovation and Development.* 6(4): 265-273

Manyong, V. M., Ikpi, A., Olayemi, J. K., Yusuf, S. A., Omonona, B. T., Okoruwa, V. and Idachaba, F. S. (2005) *Agriculture in Nigeria: identifying opportunities for increased commercialization and investment.* International Institute of Tropical Agriculture.

Mapfumo, P., Adjei-Nsiah, S., Mtambanengwe, F., Chikowo, R. and Giller, K. E. (2013) Participatory action research (PAR) as an entry point for supporting climate change adaptation by smallholder farmers in Africa. *Environmental Development*. 5: 6-22

Martin, T. G., Burgman, M. A., Fidler, F., Kuhnert, P. M., Low-Choy, S., McBride, M. and Mengersen, K. (2012) Eliciting Expert Knowledge in Conservation Science. *Obtención de Conocimiento de Expertos en Ciencia de la Conservación.* 26(1): 29-38

Mason, S. C., Ouattara, K., Taonda, S. J.-B., Palé, S., Sohoro, A. and Kaboré, D. (2015) Soil and cropping system research in semi-arid West Africa as related to the potential for conservation agriculture. *International Journal of Agricultural Sustainability*. 13(2): 120-134

Masud, M. M., Al-Amin, A. Q., Junsheng, H., Ahmed, F., Yahaya, S. R., Akhtar, R. and Banna, H. (2016) Climate change issue and theory of planned behaviour: relationship by empirical evidence. *Journal of Cleaner Production*. 113: 613-623

Matasci, C., Kruse, S., Barawid, N. and Thalmann, P. (2014) Exploring barriers to climate change adaptation in the Swiss tourism sector. *Mitigation and Adaptation Strategies for Global Change*. 19(8): 1239-1254

Matthews, J.R. (2017) Understanding Indigenous Innovation in Rural West Africa: Challenges to Diffusion of Innovations Theory and Current Social Innovation Practice. *Journal of Human Development and Capabilities*. 18 (2): 223-238

Maye, D., Ilbery, B. and Litte, R., (2012) Rationalising risk: grower strategies to manage plant disease in the UK wheat and potato sectors. *The Geographical Journal*. 178 (4): 338-347. Doi: 10.1111/j.1475-4959.2012.00485.x

Mbow, C., Skole, D., Dieng, M., Justice, C., Kwesha, D., Mane, L., El Gamri, M., Von Vordzogbe, V. and Virji, H. (2012) Challenges and prospects for REDD+ in Africa: Desk Review Of REDD+ Implementation in Africa. GLP Report No. 5. GLP-IPO, Copenhagen.

Mbow, C., Smith, P., Skole, D., Duguma, L. and Bustamante, M. (2014) Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability*. 6: 8-14

McCabe, J. T. (1994) Mobility and land use among African pastoralists: old conceptual problems and new interpretations. Pages 69-90 *in* E. M. Fratkin, K. A. Galvin, and E. A. Roth, editors. *African pastoralist systems: an integrated approach.* Lynne Reinner, Boulder, Colorado, USA.

McCusker, B. and Carr, E.R., (2006) The co-production of livelihoods and land use change: Case studies from South Africa and Ghana. *Geoforum.* 37(5): 790-804

McDaniel, C. and Gates, R. (1999) *Contemporary marketing research,* 4th edn, South-Western College Publishing, Ohio, USA.

McNeeley, S. M. (2012) Examining barriers and opportunities for sustainable adaptation to climate change in Interior Alaska. *Climatic Change*. 111(3): 835-85

Mearns, R. and Norton, A. (2010) Equity and Vulnerability in a Warming World: Introduction and Overview. **In**, Mearns, R. and Norton, A. (eds.) *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World.* The World Bank: 1-44

Mehar, M., Mittal, S. and Prasad, N. (2016) Farmers coping strategies for climate shock: Is it differentiated by gender? *Journal of Rural Studies*. 44: 123-131

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W. and Nieuwenhuis, M. (2015) The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability*. 13(1): 40-54

Meinzen-Dick, R., Adato, M., Hadda, L. and Hazell, P. (2004) *Science and Poverty: An Interdisciplinary Assessment of the Impact of Agricultural Research*. International Food Policy Research Institute.

Mekoya, A., Oosting, S. J., Fernandez-Rivera, S. and Van der Zijpp, A. J. (2008) Farmers' perceptions about exotic multipurpose fodder trees and constraints to their adoption. *Agroforestry Systems*. 73(2): 141-153

MEA (Millennium Ecosystem Assessment), (2005) Ecosystems and Human Well-being: Desertification Synthesis. World Resources Institute, Washington, DC.

Mertz, O., Mbow, C., Reenberg, A. and Diouf, A. (2009) Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel. *Environmental management*. 43 (5): 804-816.

Middleton, N. (2013) *The Global Casino: An Introduction to Environmental Issues.* 5th edn. Routledge

Mogues, T., Morris, M., Freinkman, L., Adubi, A., Ehui, S., Nwoko, C., Taiwo, O., Nege, C., Okonji, P. and Chete, L. (2008) *Agricultural Public Spending in Nigeria*. International Food Policy Research Institute.

Mohan, G. (2001) Beyond Participation: Strategies for Deeper Empowerment. **In**, Cooke, B. and Kothari, U. (eds.) *Participation: The New Tyranny?* Zed Books: 153-167

Morgan, D. L. (1997) Planning focus groups. Thousand Oaks, CA: Sage. 300

Morgan, G. A., Leech, N. and Barrett, K. (2007) *SPSS for introductory statistics: use and interpretation.* 3rd ed. Lawrence Erlbaum Associates. London

Morris, M. and Cervigni, R. (2016) Resilience and its Determinants: A conceptual. **In**, Cervigni, R. and Morris, M. (eds.) *Confronting Drought in Africa's Drylands: Opportunities* *for Enhancing Resilience.* International Bank for Reconstruction and Development/The World Bank: 37-48

Morris, M., Cervigni, R., Guo, Z., and Koo, J. (2016) The Central Role of Drylands in Africa's Development Challenge. **In,** Cervigni R., and Morris M., (eds.) *Confronting Drought in Africa's Drylands: Opportunities for Enhancing Resilience.* Africa Development Forum series. Washington, DC: World Bank. Doi: 10.1596/978-1-4648-0817-3.

Mortimore, M. (1998) *Roots in the African dust: Sustaining the Sub-Saharan drylands.* Cambridge University Press

Mortimore, M. (2000) *Profile of rainfall change and variability in the Kano-Maradi region, 1960-2000*

Mortimore, M. (2003) Long-term Change in African drylands: Can recent history point towards development pathways? *Oxford Development Studies.* 31(4): 503-516.

Mortimore, M. J. (2005) Dryland Development: Success Stories from West Africa. *Environment*. 45: 10-21

Mortimore, M. and Adams, W. M. (1999) *Working the Sahel: environment and society in northern Nigeria.* Routledge. (Routledge Global Environmental Change Series).

Mortimore, M., and Tiffen, M. (1995) Population and environment in time perspective: the Machakos story. **In**, Binns T. (eds.) *People and Environment in Africa.* Wiley, Chichester: 69-89.

Mortimore, M., Adams, B. and Harris, F. (2000) *Poverty and systems research in the drylands*. International Institute of Environment and Development.

Mortimore, M.J., and Adams W.M. (2001) Farmer adaptation, change and 'crisis' in the Sahel. *Global Environmental Change.* 11: 49-57.

Mortimore, M. and Harris, F. (2005) Do small farmers' achievements contradict the nutrient depletion scenarios for Africa? *Land Use Policy 22: 43-56.*

Mortimore, M., Anderson, S., Cotula, L., Faccer, K., Hesse, C., Mwangi, A., Nyangena, W. and Skinner, J. (2008) *Drylands - an Economic Asset for Rural Livelihoods and Economic Growth.* IUCN, IIED and UNDP/DDC

Mortimore, M. with contributions from S. Anderson, L. Cotula, J. Davies, K. Faccer, C. Hesse, J. Morton, W. Nyangena, J. Skinner, and C. Wolfangel (2009) *Dryland Opportunities: A new paradigm for people, ecosystems and development* (pp. 1–2). Switzerland: IUCN; United Kingdom: IIED, and Kenya: UNDP/DDC.

Morton, J. F. (2007) The impact of climate change on smallholder and subsistence agriculture. *PNAS*. 104(50): 19680-19685.

Mosse, D. (2001) 'People's Knowledge', Participation and Patronage: Operations and Representations in Rural Development. **In**, Cooke, B. and Kothari, U. (eds.) *Participation: The New Tyranny?* Zed Books: 16-35

Mumby, P. J., Chollett, I., Bozec, Y. M. and Wolff, N. H. (2014) Ecological resilience, robustness and vulnerability: how do these concepts benefit ecosystem management? *Current Opinion in Environmental Sustainability*. 7: 22-27

Murphy, S. (2012) *Changing Perspectives: Small-scale farmers, markets and globalisation*. International Institute for Environment and Development (IIED).

Mwangi, E., and Dohrn, S. (2008) Securing access to drylands resources for multiple users in Africa: A review of recent research. *Land Use Policy*. 25: 240–248.

Myers, N. (1993) Environmental Refugees in a Globally Warmed WorldEstimating the scope of what could well become a prominent international phenomenon. *BioScience*. 43(11): 752-761

Myers-Smith, I. H., Trefry, S.A., and Swarbrick, V.J. (2012) Resilience: easy to use but hard to define. Ideas Ecol. Evol. 5, 44–53.

M'Biandoun, M., Dongmo, A.L. and Balarabe, O. (2010) Culture systems on vegetation cover in Central Africa: technical conditions and for its socioeconomic development. L. Seiny-Boukar, P. BOUMARD. Savannas in African development: innovating to last Apr 2009, Garoua, Cameroon. CIRAD, 10 p.

Nana, P. D, Dugue, P., Mkomwa, S., Da Sansan, J. B., Guillaume, E., Bougoum, H., Zerbo, I., Ganou, S., Andrieu, N. and Douzet J. (2014) Conservation Agriculture in West and Central Africa. **In**, Jat R.A. Sahrawat K.L and Kassam A.H. (eds.) *Conservation Agriculture: Global Prospects and Challenges*. CAB International: 311-338.

NAP (2000) The National Action Programme to Combat Desertification and Mitigate the Effect of Drought Federal Ministry of Environment, Abuja, Nigeria. Available at: http://www.unccd.int/ActionProgrammes/nigeria-eng2001.pdf. Accessed on 06/07/2016.

National Bureau of Statistics. (2016) *Nigerian Gross Domestic Product Report*. [online] Federal Government of Nigeria. Available from: http://nigerianstat.gov.ng/report/434 [Date accessed: 12/10/2016].

National Bureau of Statistics and The Federal Ministry of Agriculture and Rural Development and The World Bank (2014). *LSMS-Integrated Surveys on Agriculture General Household Survey Panel 2012/2013*Available from: http://siteresources.worldbank.org/INTLSMS/Resources/3358986-1233781970982/5800988-1282216357396/7337519-1388758418241/GHS_Panel_Survey_Report_Wave_2.pdf

Ndamani, F. and Watanabe, T. (2015) Determinants of farmers' adaptation to climate change: A micro level analysis in Ghana. *Scienta Agricola*. 73(3): 201-208

Neely, C., Bunning, S. & Wilkes, A. (eds). (2009) Review of evidence on drylands pastoral systems and climate change. Implications and opportunities for mitigation and adaptation. *Food and Agriculture Organisation of the United Nations.* Rome. Downloadable from ftp://ftp.fao.org/docrep/fao/012/i1135e/i1135e00.pdf

Nelson, D. R., Adger, W. N. and Brown, K. (2007) Adaptation to Environmental Change: Contributions of a Resilience Framework. *Annual Review of Environment and Resources*. 32(1): 395-419

Nerbonne, J.F., and R. Lentz. (2003) Rooted in grass: challenging patterns of knowledge exchange as a means of fostering social change in a southeast Minnesota farm community. *Agriculture and Human Values* 20(1): 65-78.

NESREA. (2016) *ABOUT NESREA.* [online] Available from: http://nesrea.gov.ng/about/index.html [Date accessed: 18/07/2016]

Netting, R. M. (1989) *Smallholders, householders, freeholders: why the family farm works well worldwide.* Westview Press.

Nichol, J. E. (1991) Monitoring the effect of dams on fadama cultivation in the Jakara River basin, using remote sensing techniques. IN OLOFIN, E. A. & PATRICK, S. (Eds.) *Land Administration and Development in Northern Nigeria: Case Studies, Kano.* Kano, Department of Geography, BUK.

Nicholson, S. E., Tucker, C. J. and Ba, M. B. (1998) Desertification, Drought, and Surface Vegetation: An Example from the West African Sahel. *American Meteorological Society*. 79(5): 815-829.

Niles, M. T., Brown, M. and Dynes, R. (2016) Farmer's intended and actual adoption of climate change mitigation and adaptation strategies. *Climatic Change*. 135(2): 277-295

NiMet (1987-2007) Annual Climate Data series. Nigerian Meteorological Agency, Department of Meteorological Service, Samonda, Ibadan, Nigeria.

Nkonya, E., Mirzabaev, A. and von Braun, J. (2016) Economics of Land Degradation and Improvement: An Introduction and Overview. **In**, Nkonya, E., Mirzabaev, A. and von Braun, J. (eds.) *Economics of Land Degradation and Improvement - A Global Assessment for Sustainable Development.* Springer Open: 1-14

Nnoli, O. (1990) Desertification, refugees and regional conflict in West Africa. *Disasters*. 14(2): 132-139

Notenbaert, A., M., Herrero, R. L., Kruska, L., You, S., Wood, P. E., Thornton. and A. Omolo. (2009) *Classifying livestock production systems for targeting agricultural research and development in a rapidly changing world.* International Livestock Research Institute (ILRI) Discussion Paper 19. ILRI, Nairobi, Kenya.

Nwafor, M. (2008) *Literature review of development targets in Nigeria*. Ibadan: International Institute of Tropical Agriculture.

Obioha, E. E. (2009) Climate Variability, Environment Change and Food Security Nexus in Nigeria. *J Hum Ecol.* 26(2): 107-121.

Odjugo, P. A. O. (2010) General Overview of Climate Change Impacts in Nigeria. *J Hum Ecol*, 29(1): 47-55.

Ogen, O. (2007) The Agricultural Sector and Nigeria's Development: Comparative Perspectives from the Brazilian Agro-Industrial Economy. *Nebula*. 4(1): 184-194

Okoli, C. and Pawlowski, S. D. (2004) The Delphi Method as a Research Tool: An Example, Design Considerations and Applications. *Information & Management*. 42(1): 15-29

Okonyo, J.S., Syndikus, K., and Kroschel, J. (2013) Farmers' Perception of and Coping Strategies to Climate Change: Evidence from Six Agro-Ecological Zones of Uganda. *Journal of Agricultural Science.* 5(8): 252-263

Okpara, J. N., Tarhule, A. A. and Perumal, M. (2013) Study of Climate Change in Niger River Basin, West Africa: Reality Not a Myth. Open science. Available from: http://cdn.intechopen.com/pdfs-wm/41986.pdf. Accessed on 18/10/2015.

Okoro, D. and Ujah, O. C. (2009) *Agricultural Policy and Budget Analysis in Nigeria (1999-2007): Perspectives and Implications for SLISSFAn Project States.* [online] Available from: http://www.interreseaux.org/IMG/pdf_Agric_Policy_Budget_Analysis_in_Nigeria_SLISSFAN.pdf [Date: 10/10/2015].

Ola-Adams, B. A. and Okali, D. U. U. (2008) Conservation of biodiversity of Nigerian Drylands. **In**, Lee, C. and Schaaf, T. (eds.) *The Future of Drylands.* Springer: 447-455.

Oladipupo, A. M., Egbenayabuwa, O. F. and Sede, C. (2014) Effect of T&V innovation on income and farmers' performance in Edo State Nigeria. *American Journal of Agriculture and Forestry*. 2(4): 159-167

Olomola, A., Mogues, T., Olofinbiyi, T., Nwoko, C., Udoh, E., Alabi, R., Onu, J. and Woldeyohannes, S. (2014) *Analysis of Agricultural Public Expenditures in Nigeria: Examination at the Federal, State and Local levels*. International Food Policy Research Institute.

Olsson, L., Eklundh, L. and Ardö, J. (2005) A recent greening of the Sahel—trends, patterns and potential causes. *Journal of Arid Environments*. 63(3): 556-566

Omanya, G. O. and Pasternak, D, eds. (2005) *Sustainable Agriculture Systems for the Drylands. Proceedings of the International Symposium for Sustainable Dryland Agriculture Systems, 2–5 December 2003, Niamey, Niger.* International Crops Research Institute for the Semi-Arid Tropics, Niamey, Niger. ISBN 9290664770. Available at: http://oar.icrisat.org/553/1/RA_0404.pdf. Accessed on 12/09/16.

Onwuegbuzie, A. J., and Collins, K. M. T. (2007). A typology of mixed methods sampling designs in social science research. *The Qualitative Report*, *12*(2), 281-316. Retrieved [13/10/2015], from http://www.nova.edu/ssss/QR/QR12-2/onwuegbuzie2.pdf

Ormston R., Spencer, L., Barnard, M. and Snape, D. (2014) The Foundations of Qualitative Research. **In,** Ritchie, J., Lewis J., Nicholls C.M. and Ormston R. (ed.) (2014) *Qualitative research practice; a guide for social science students and researchers.* 2nd edn. London SAGE Publications Ltd. 1-25

Oruonye, E.D. (2013) The impacts of the drying Lake Chad on rural dwellers of Africa. *Spanish Journal of Rural Development.* 4(3): 15-20.

Osbahr, H., Twyman, C., Neil Adger, W. and Thomas, D. S. G. (2008) Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique. *Geoforum*. 39: 1951-1964.

Oweis, T. Y., Prinz, D. and Hachum, A. Y. (2012) *Water Harvesting for Agriculture in the Dry Areas.* CRC Press

Oyatoye, E. T. O. (1984) The administration of agricultural development in Nigeria: An assessment of past and present agricultural policies. *Agricultural Administration*. 15(2): 101-113.

O'Laughlin, B., (2002) Proletarianisation, agency and changing rural livelihoods: forced labour and resistance in colonial Mozambique. Journal of Southern African Studies 28 (3), 511–530.

Øygard, R., Vedeld, T. and Aune, J. (1999) *Good Practices in Drylands Management.* The World Bank

Pallant, J. (2013) *SPSS Survival Manual: A step by step guide to data analysis using IBM SPSS*. 5th ed. Berkshire: Open University Press.

Pathak P., Sahrawat K.L., Wani S.P., Sachan R.C., and Sudi. R. (2009) **In**, S.P Wani, J. Rockström and T Oweis (eds.) *Rainfed Agriculture: Unlocking the Potential.* CAB International: 197-221

Patt, A. and Gwata, C. (2002) Effective seasonal climate forecast applications: examining constraints for subsistence farmers in Zimbabwe. *Global Environmental Change*. 12(3): 185-195

Pennisi, E. (2008) The Blue Revolution, Drop by Drop, Gene by Gene. *Science*. 320(5873): 171

Phalan, B., Balmford, A., Green, R. E. and Scharlemann, J. P. W. (2011) Minimising the harm to biodiversity of producing more food globally. *Food Policy*. 36: S62-S71

Philip, D., Nkonya, E., Pender, J. and Oni, O. A. (2009) *Constraints to Increasing Agricultural Productivity in Nigeria: A Review*. International Food Policy Research Institute.

Phillips, P. W. B. (2002) Biotechnology in the global agri-food system. *Trends in Biotechnology*. 20(9): 376-381

Pimm, S.L. (1984) The complexity and stability of ecosystems. Nature 307:321–6

Porter, G. (1995) Adapting to Environment and market: trade and marketing in northern Nigeria. **In**, Binns, T. (ed.) *People and Environment in Africa.* Binns, Tony: 197-204

Poulton, C., Dorward, A. and Kydd, J. (2005) 'The future of small farms: new directions for services, institutions and intermediation', Paper presented at the The Future of Small Farms Workshop, Imperial College, Wye, UK, pp.19–36.

Powell, C. (2003) The Delphi technique: myths and realities. *Journal of Advanced Nursing*. 41(4): 376-382

Pretty, J. N. (1997) The sustainable intensification of agriculture. *Natural Resources Forum*. 21(4): 247-256

Pretty, J. (2008) Agricultural sustainability: concepts, principles and evidence. *Phil. Trans. R. Soc. B.* 363: 447–465.

Pretty, J. N., Morison, J. I. L. and Hine, R. E. (2003) Reducing food poverty by increasing agricultural sustainability in developing countries. *Agriculture, Ecosystems & Environment*. 95(1): 217-234

Pretty, J. N., Noble, A. D., Bossio, D., Dixon, J., Hine, R. E., Penning de Vries, F. W. T. and Morison, J. I. L. (2006) Resource-Conserving Agriculture Increases Yields in Developing Countries. *Environmental Science & Technology*. 40(4): 1114-1119.

Pretty, J., Sutherland, W. J., Ashby, J., Auburn, J., Baulcombe, D., Bell, M., Bentley, J., Bickersteth, S., Brown, K., Burke, J., Campbell, H., Chen, K., Crowley, E., Crute, I., Dobbelaere, D., Edwards-Jones, G., Funes-Monzote, F., Godfray, H. C. J., Griffon, M., Gypmantisiri, P., Haddad, L., Halavatau, S., Herren, H., Holderness, M., Izac, A. M., Jones, M., Koohafkan, P., Lal, R., Lang, T., McNeely, J., Mueller, A., Nisbett, N., Noble, A., Pingali, P., Pinto, Y., Rabbinge, R., Ravindranath, N. H., Rola, A., Roling, N., Sage, C., Settle, W., Sha, J. M., Luo, S. M., Simons, T., Smith, P., Strzepeck, K., Swaine, H., Terry, E., Tomich, T. P., Toulmin, C., Trigo, E., Twomlow, S., Vis, J. K., Wilson, J. and Pilgrim, S. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*. 8(4): 219-236

Prislin, R. and Ouellette, J. (1996) When it is embedded, it is potent: effects of general attitude embeddedness on formation of specific attitudes and behavioural intention. *Pers. Soc. Psychol. Bull.* 22:845-61

Pruneau, D., Khattabi, A., and Demers, M. (2010) Challenges and Possibilities in Climate Chnage Education. *US China Education Review*. 15-23.

Raju, K.V. and Wani, S. P. (2016) Drylands for Food Security: A Macro Perspective. **In**, Raju, K.V. and Wani, S. P. (eds.) *Harnessing dividends from drylands: Innovative scaling up with soil nutrients*. CAB International. Wallingford: 1-33

Rand Corporation. (2017) *Delphi Method | RAND*. [online] Available from: https://www.rand.org/topics/delphi-method.html [Date accessed: 15/05/2017]

Reardon, T. and Vosti, S. A. (1997a) Policy Analysis of Conservation Investments: Extensions of Traditional Adoption Research. **In**, Vosti, S. A. and Reardon, T. (eds.) *Sustainability, Growth, and Poverty Alleviation: A Policy and Agroecological Perspective.* The Johns Hopkins University Press: 135-145

Reardon, T. and Vosti, S. A. (1997b) Poverty-Environment links in rural Areas of Developing Countries. **In**, Vosti, S. A. and Reardon, T. (eds.) *Sustainability, Growth, and Poverty Alleviation: A Policy and Agroecological Perspective.* The Johns Hopkins University Press: 47-65.

Reed, M. S. (2008) Stakeholder participation for environmental management: A literature review. *Biological Conservation*. 141(10): 2417-2431

Reed, M. S. and Stringer, L. C. (2015) *Climate change and desertification: Anticipating, assessing & adapting to future change in drylands*. UNCCD.

Reed, M. S. and Stringer, L. C. (2016) *Land Degradation, Desertification and Climate Change: Anticipating, assessing and adapting to future change.* Earthscan from Routledge

Reij, C. P. and Smaling, E. M. A. (2008) Analyzing successes in agriculture and land management in Sub-Saharan Africa: Is macro-level gloom obscuring positive micro-level change? *Land Use Policy*. 25: 410-420.

Reij, C. and Steeds, D. (2003) *Success Stories in Africa's Drylands: Supporting Advocates and Answering Skeptics*, CIS/Centre for International Cooperation, Vrije Universiteit Amsterdam, Amsterdam.

Reilly, J, Baethgen, W, Chege, F, van de Geijn, S, Erda, L, Iglesias, A, Kenny, G, Patterson, D, Rogasik, J, Rotter, R, Rosenzweig, C, Somboek, W & Westbrook, J, (1996) Agriculture in a changing climate: Impacts and adaptations. **In**, Watson, R, Zinyowera, M, Moss, R & Dokken, D (Eds.), 1996. Climate Change 1995: Impacts, adaptations, and mitigation of climate change: Scientific-technical analyses. Cambridge University Press for the Intergovernmental Panel on Climate Change, Cambridge, UK.

Reimer, A.P., Gramig, B.M. and Prokopy, L.S. (2013) Farmers and conservation programs: explaining differences in environmental quality incentives program application between states. *Journal of Soil Water Conservation.* 68:110-119

Reynolds, J. F., Stafford Smith, D. M., Lambin, E. F., Turner, B. L., Mortimore, M., Batterbury, S. P. J., Downing, T. E., Dowlatabadi, H., Fernandez, R. J., Herrick, J. E., Huber-Sannwald, E., Jiang, H., Leemans, R., Lynam, T., Maestre, F. T., Ayarza, M. and Walker, B. (2007) Global desertification: Building a science for dryland development. *Science*. 316(5826): 847-851

Ribot, J. (2010) Vulnerability Does Not Fall from the Sky: Towards Multiscale, Pro-Poor Climate Policy. **In**, Mearns, R. and Norton, A. (eds.) *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World.* The World Bank: 47-74

Richard, R., van der Pligt, J., & de Vries, N. (1996) Anticipated affect and behavioral choice. *Basic and Applied Social Psychology*. 18: 111-129.

Ritchie, J. and Ormston R. (2014) The Applications of Qualitative methods to Social Research. **In,** Ritchie, J., Lewis J., Nicholls C.M. and Ormston R. (ed.) (2014) *Qualitative research practice; a guide for social science students and researchers.* 2nd edn. London SAGE Publications Ltd. 27-46

Rivera, W. I. and Alex, G. (2004) The Continuing Role of Government in Pluralistic Extension Systems. *Journal of International Agricultural and Extension Education*. 11(3): 41-51

Robinson, J. (2004) Squaring the circle? Some thoughts on the idea of sustainable development. *Ecological Economics*. 48(4): 369-384

Robson, C. (2011) *Real World Research: A Resource for Users of Social Research Methods in Applied Settings.* 3rd edn. Wiley & Sons

Rockström, J. (2001) Green water security for the food makers of tomorrow: windows of opportunity in drought-prone savannahs. *Water Science & Technology*. 43(4), 71-78

Rockström, J., Barron, J., and Fox P. (2003) Water Productivity in Rain-fed Agriculture: Challenges and Opportunities for Smallholder Farmers in Drought-prone Tropical Agroecosystems CAB International. **In**, *Water Productivity in Agriculture: Limits and Opportunities for Improvement* (eds J.W. Kijne, R. Barker and D. Molden).

Rockström, J., Karlberg, L., Wani, S.P., Barron, J., Hatibu, N., Oweis, T., Bruggeman, A., Farahani, J., Qiang, Z., (2010). Managing water in rainfed agriculture – the need for a paradigm shift. Agricultural Water Management Comprehensive Assessment of Water Management in Agriculture 97 (4), 543–550.

Rockström, J., and Karlberg L. (2009) Zooming in on the Global Hotspots of Rainfed Agriculture in Water-constrained Environments. **In**, S.P Wani, J. Rockström and T Oweis (eds.) *Rainfed Agriculture: Unlocking the Potential.* CAB International: 36-43

Rogers, B. A. (1999) *Policy recommendations on agriculture.* [online] Available from: http://nigeriaworld.com/feature/article/agric_policy.html [Date accessed: 18/04/2017]

Rogers, E.M., (1995) Diffusion of innovations. New York: Free Press.

Rogers, E.M. (2003) Diffusion of innovations, 5th edn. Simon and Schuster, Inc, New York

Rosenstock, T.S. et al., (2013) Toward a protocol for quantifying the greenhouse gas balance and identifying mitigation options in smallholder farming systems. *Environ. Res. Lett*. 8 (2013) 021003 (5pp)

Rosset, P. M. and Altieri, M. A. (2017) *Agroecology: Science and Politics.* Vol. 7. Fernwood Publishing

Royal Society (1992*) Risk: Analysis, Perception and Management.* London, Royal Society.

Royer-Miller, M. (2010) *A Farmer's Mini-Handbook: Grow Biointensive Sustainable Mini-Farming.* [online] Ecology Action. Available from: http://www.growbiointensive.org/PDF/FarmersHandbook.pdf [Date accessed: 02/03/2017]

Russo, T., Alfredo, K., and Fisher, J. (2014) Sustainable Water Management in Urban, Agricultural, and Natural Systems. *Water*. 6: 3934-3956.

Ruttan, V. W. (1997) Sustainable Growth in Agricultural Production: Poetry, Policy, and Science. **In**, Vosti, S. A. and Reardon, T. (eds.) *Sustainability, Growth, and Poverty Alleviation: A Policy and Agroecological Perspective.* The Johns Hopkins University Press: 19-33.

Safriel, U., Adeel, Z., Niemeijer, D., Puigdefabregas, J., White, R., Lal, R.,Winslow, M., Ziedler, J., Prince, S., and Archer, E. (2005) Dryland systems, in: Ecosystems and Human Well-being: Current State and Trends, edited by: Ash, N., Hassan, R., and Scholes, R., Findings of the Condition and Trends Working Group, Island Press, Washington, D.C., 623–662.

Safriel, U. and Adeel, Z. (2008) Development paths of drylands: thresholds and sustainability. *Sustainability Science*. 3(1): 117-123

Saliu, O. J. and Age, A. I. (2009) Privatization of Agricultural Extension Services in Nigeria-Proposed Guidelines for Implementation. *Journal of Sustainable Development in Africa*. 11(2): 160-176

Samaradiwakara, G. D. M. N. and Gunawardena, C. G. (2014) Comparison of Existing Technology Acceptance Theories and Models to suggest a well improved Theory/Model. *International Technical Sciences Journal*. 1(1): 21-36

Sandford, S, (1983) *Management of pastoral development in the Third World.* Chichester: John Wiley

Sanginga, N., Dashiell, K. E., Diels, J., Vanlauwe, B., Lyasse, O., Carsky, R. J., & Ortiz, R. (2003) Sustainable resource management coupled to resilient germplasm to provide new intensive cereal–grain–legume–livestock systems in the dry savanna. *Agriculture, Ecosystems & Environment.* 100(2): 305-314.

Sansoucy, R. (1997) Livestock.Driving force for food security and sustainable development. *IRDC currents* No 13/14:4.11.

Sanyal, P. and Babu, S. (2010) *Policy Benchmarking and Tracking the Agricultural Policy Environment in Nigeria*. International Food Policy Research Institute.

Saunders, P., Lewis, P. and Thornhill, A. (2012) *Research methods for business students.* Sixth edn. Pearson

Scapolo, F. and Miles, I. (2006) Eliciting experts' knowledge: A comparison of two methods. *Technological Forecasting and Social Change*. 73(6): 679-704

Scheibe, M., Skutsch, M., and J. Schofer, J. (2002) Experiments in Delphi Methodology. In: Linstone, H.A. and Turoff, M. (Eds.), The Delphi Method: Techniques and Applications. Newark: New Jersey Institute of Technology. Pp. 257-281

Schultz, P.W. and Oskamp, S. (1996) Effort as a moderator of the attitude-behaviour relationship: general environmental concern and recycling. *Soc. Psychol. Q.* 59: 375-83

Scoones, I. (2009) Livelihoods perspectives and rural development. *The Journal of Peasant Studies*. 36(1): 171-196

Scoones, I. (1995) Policies for pastoralists: new directions for pastoral development in Africa. **In**, Binns, T. (ed.) *People and Environment in Africa.* John Wiley & Sons: 23-30

Scoones, I. and Wolmer, W. (2002) Pathways of Change: Crop-Livestock Integration in Africa. **In**, Scoones, I. and Wolmer, W. (eds.) *Pathways of Change in Africa: Crops, Livestock & Livelihoods in Mali, Ethiopia & Zimbabwe.* James Currey Ltd: 1-32

Scoones, I., Devereux, S. and Haddad, L. (2005) Introduction: New Directions for African Agriculture. *IDS Bulletin*. 36(2): 1-12

Scott, A. (2011) Focussing in on focus groups: Effective participative tools or cheap fixes for land use policy? *Land Use Policy*. 28(4): 684-694

Sensier, M., Bristow, G. and Healy, A. (2016) Measuring Regional Economic Resilience across Europe: Operationalizing a complex concept. *Spatial Economic Analysis*. 11(2): 128-151

Serenari, C., Leung, Y.-F., Attarian, A. and Franck, C. (2012) Understanding environmentally significant behavior among whitewater rafting and trekking guides in the Garhwal Himalaya, India. *Journal of Sustainable Tourism*. 20(5): 757-772

Shahadu, H. (2012) Towards a Theory of Social Adaptation to Climate Change in Africa: An Empirical Study of Socio-cognitive Determinants of Youth Climate Behaviour in Northern Ghana. Lambert Academic Publishing, ISBN: 3847344994

Sharma, N.K. and Singh R.J. (2013) Agronomic practices for Erosion Control. *Popular Kheti*.1(30):57-60.

Sherwood, A. (2013) Community adaptation to climate change: exploring drought and poverty traps in Gituamba location, Kenya. *Journal of Natural Resources Policy Research*.5:2-3, 147-161.

Shiferaw, B., Okello, J. and Reddy, V. R. (2009) Challenges of Adoption and Adaptation of Land and Water Management Options in Smallholder Agriculture: Synthesis of Lessons and Experiences. **In**, Wani, S. P., Rockstrom, J. and Oweis, T. (eds.) *Rainfed Agriculture: Unlocking the Potential.* CAB International: 258-275

Siamwalla, A. (1997) The Relationship between Trade and Environment, with Special Reference to Agriculture. **In**, Vosti, S. A. and Reardon, T. (eds.) *Sustainability, Growth, and Poverty Alleviation: A Policy and Agroecological Perspective.* The Johns Hopkins University Press: 103-118

Sietz, D., Boschütz, M. and Klein, R. J. T. (2011) Mainstreaming climate adaptation into development assistance: rationale, institutional barriers and opportunities in Mozambique. *Environmental Science & Policy*. 14(4): 493-502

Silverman, D. (2014) *Interpreting qualitative data.* Fifth edn. SAGE Publications

Slegers M.F.W., and Stroosnijder L. (2008) Beyond the Desertification Narrative: A Framework for Agricultural Drought in Semi-arid East Africa. *Ambio*. 37:5.

Smet, M. and Ward, D. (2006) Soil quality gradients around water-points under different management systems in a semi-arid savanna, South Africa. *Journal of Arid Environments*. 64(2): 251-269

Smit, B. and Skinner, M.W. (2002) Adaptation options in agriculture to climate change: A typology. *Mitigation and Adaptation Strategies for Global Change* **7:** 85–114

Smit, B. and Wandel, J. (2006) Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*. 16(3): 282-292

Smit, B., McNabb, D. and Smithers, J. (1996) Agricultural adaptation to climatic variation, *Climate Change* **33**, 7–29

Snrech, S. (1995) Preparing for the future: a vision of West Africa in the year 2020. Summary Report of the West Africa Long Term Perspective Study. OECD—Club du Sahel and CILSS, Paris.

Soon, J. M. and Baines, R. N. (2012) Food safety training and evaluation of handwashing intention among fresh produce farm workers. *Food Control*. 23(2): 437-448

Soon, J. M., Davies, W. P., Chadd, S. A. and Baines, R. N. (2012) A Delphi-based approach to developing and validating a farm food safety risk assessment tool by experts. *Expert Systems with Applications*. 39(9): 8325-8336

Spencer, D. S. C. and Polson, R. A. (1997) Agricultural Growth and Sustainability: Conditions for Their Compatibility in the Humid and Subhumid Tropics of Africa. **In**, Vosti, S. A. and Reardon, T. (eds.) *Sustainability, Growth, and Poverty Alleviation: A Policy and Agroecological Perspective.* The Johns Hopkins University Press: 191-207.

Speranza, C.I., Kiteme, B., Ambenje, P., Wiesmann, U. and Makali, S. (2010) Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya. *Climatic Change*. 100(2): 295-315

Srinivasarao, Ch., Venkateswarlu B., Lal R., Singh A.K., Kundu S., and Jakkula, V.S. (2013) Carbon Sink Capacity and Agronomic Productivity of Soils of Semiarid Regions of India. **In,** Lal, R. and Stewart B.A. (eds.) *Principles of Sustainable Soil Management in Agroecosysems.* Taylor & Francis Group: 423-476

Standish, R. J., Hobbs, R. J., Mayfield, M. M., Bestelmeyer, B. T., Suding, K. N., Battaglia, L. L., Eviner, V., Hawkes, C. V., Temperton, V. M., Cramer, V. A., Harris, J. A., Funk, J. L. and Thomas, P. A. (2014) Resilience in ecology: Abstraction, distraction, or where the action is? *Biological Conservation*. 177: 43-51

Stebbing, E. P. (1935) The Encroaching Sahara: The Threat to the West African Colonies. *The Geographical Journal*. 85(6): 506-519.

Stehr, N., von Storch, H., (1995) The social construct of climate and climate change. *Climate Research.* 5: 99 -105.

Steinert, M. (2009) A dissensus based online Delphi approach: An explorative research tool. *Technological Forecasting and Social Change*. 76(3): 291-300

Stern, N. (2006) *The Economics of Climate Change: The Stern Review*. Cambridge, UK: Cambridge University Press

Stringer, L. C., Dyer, J. C., Reed, M. S., Dougill, A. J., Twyman, C. and Mkwambisi, D. (2009) Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science & Policy*. 12(7): 748-765

Struik, P. C., Kuyper, T. W., Brussaard, L. and Leeuwis, C. (2014) Deconstructing and unpacking scientific controversies in intensification and sustainability: why the tensions in concepts and values? *Current Opinion in Environmental Sustainability*. 8: 80-88.

Swe, L. M. M., Shrestha, R. P., Ebbers, T. and Jourdain, D. (2015) Farmers' perception of and adaptation to climate-change impacts in the Dry Zone of Myanmar. *Climate and Development*. 7(5): 437-453

Tabachnick, B. G. and Fidell, L. S. (2014) *Using Multivariate Statistics.* 6th edn. Pearson

Tabor, J.A. (1995) Improving crop yields in the Sahel by means of water-harvesting. *Journal of Arid Environments.* 30: 83-106.

Tambo J.A. and Abdoulaye T. (2012) Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria. *Mitig Adapt Strateg Glob Change.* 17:277–292

Tambo, J. A. and Abdoulaye, T. (2013) Smallholder farmers' perceptions of and adaptations to climate change in the Nigerian savanna. *Regional Environmental Change*. 13(2): 375-388

Tendall, D. M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q. B., Kruetli, P., Grant, M. and Six, J. (2015) Food system resilience: Defining the concept. *Global Food Security*. 6: 17-23

Tenywa, M.M., Zake J.Y.K. and Lal R. (2013) Building upon traditional Knowledge to Enhance Resilience of Soils in Sub-Saharan Africa. **In,** Lal, R. and Stewart B.A. (eds.) *Principles of Sustainable Soil Management in Agroecosysems.* Taylor & Francis Group: 109-140

Terry, D. J., Hogg, M. A. and White, K. M. (1999) The theory of planned behaviour: Self-identity, social identity and group norms. *British Journal of Social Psychology*. 38(3): 225-244

Thaler, R. H. and Sunstein, C. R. (2009) *Nudge: Improving decisions about health, wealth and happiness.* Revised edn. Penguin Books

The Montpellier Panel (2015) *The farms of change: African smallholders responding to an uncertain climate future.*

Thomas, R. J. (2008a) 10th Anniversary review: Addressing land degradation and climate change in dryland agroecosystems through sustainable land management. *Journal of Environmental monitoring*. 10(5): 595-603

Thomas, R. J. (2008b) Opportunities to reduce the vulnerability of dryland farmers in Central and West Asia and North Africa to climate change. *Agriculture, Ecosystems and Environment*. 126: 36–45.

Thomas, D. S. G and Middleton, N.J. (1994) *Desertification Exploding the Myth.* John Wiley & Sons Ltd, Chichester

Thomas, D. S. G. and Twyman, C. (2005) Equity and justice in climate change adaptation amongst natural-resource-dependent societies. *Global Environmental Change*. 15(2): 115-124

Thompson, J. and Scoones, I. (2009) Addressing the dynamics of agri-food systems: an emerging agenda for social science research. *Environmental Science & Policy*. 12: 386-397

Thornton, P. K. and Wilkens, P. W. (1998) Risk assessment and food security. **In**, Tsuji, G. Y., Hoogenboom, G. and Thornton, P. K. (eds.) *Understanding Options for Agricultural Production.* Vol. 7. Kluwer Academic Publishers: 329-345.

Thurstone, L. L. (1947) *Multivariate factor analysis.* University of Chicago Press

Tiffen, M. and Mortimore, M. (2002) Questioning desertification in dryland sub-Saharan Africa. *Natural Resources Forum*. 26: 218-233.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R. and Polasky, S. (2002) Agricultural sustainability and intensive production practices. *NATURE*. 418: 671-677

Tittonell P. (2014) Ecological intensification of agriculture — sustainable by nature. *Current Opinion in Environmental Sustainability*. (8):53–61

Tittonell, P., Scopel, E., Andrieu, N., Posthumus, H., Mapfumo, P., Corbeels, M., van Halsema, G. E., Lahmar, R., Lugandu, S., Rakotoarisoa, J., Mtambanengwe, F., Pound, B., Chikowo, R., Naudin, K., Triomphe, B. and Mkomwa, S. (2012) Agroecology-based aggradation-conservation agriculture (ABACO): Targeting innovations to combat soil degradation and food insecurity in semi-arid Africa. *Field Crops Research*. 132: 168-174

Toulmin, C. and Brock, K. (2016) Desertification in the Sahel: Local Practice Meets Global Narrative. **In**, Behnke, R. H. and Mortimore, M. (eds.) *The End of Desertification? Disputing Environmental Change in the Drylands*. Springer: 37-64

Tschakert, P. and Dietrich, K. A. (2010) Anticipatory Learning for Climate Change Adaptation and Resilience. *Ecology & Society*. 15(2): 1-18.

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J. and Whitbread, A. (2012) Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation*. 151(1): 53-59

UNCCD, UNDP, and UNEP (2009) Climate Change in the African Drylands: Options and Opportunities for Adaptation and Mitigation. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany, United Nations Development Programme (UNDP), New York, NY, USA, and United Nations Environment Programme (UNEP), Nairobi, Kenya, 54 pp.

UNCCD (2016) *UNCCD - About the Convention.* [online] Available from: http://www.unccd.int/en/about-the-convention/Pages/About-the-Convention.aspx [Date accessed: 18/07/2016]

UNCTAD (2009) 'Sustaining African agriculture: organic production', Policy Brief No. 6, February 2009, United Nations Conference on Trade and Development (UNCTAD).

UNDESA (2016) *World population projected to reach 9.7 billion by 2050 | UN DESA | United Nations Department of Economic and Social Affairs.* [online] United Nations. Available from: http://www.un.org/en/development/desa/news/population/2015-report.html [Date accessed: 07/10/2016].

UNDP, and UNCCD (2011) The forgotten Billion: MDG achievement in the drylands. United Nations Development Programme (UNDP), New York, NY, USA, United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany, 67 pp.

UNEP (United Nations Environment Programme), (1997) World atlas of desertification 2ED. UNEP, London.

UNEP (United Nations Environmental Programme), (2016) *ERISC PHASE II: How food prices link environmnetal constraints to sovereign credit risk*Available from: http://www.unepfi.org/fileadmin/documents/ERISC_Phase2.pdf

United States National Weather Service (2008) *Drought: PUBLIC FACT SHEET*. [online] Available from: http://www.nws.noaa.gov/os/brochures/climate/DroughtPublic2.pdf [Date accessed: 9/11/2015].

Urruty, N., Tailliez-Lefebvre, D. and Huyghe, C. (2016) Stability, robustness, vulnerability and resilience of agricultural systems. A review. *Agronomy for Sustainable Development*. 36(1): 15

Van Duivenbooden, N., Pala, M., Studer, C., Bielders, C. L. and Beukes, D. J. (2000) Cropping systems and crop complementarity in dryland agriculture to increase soil water use efficiency: a review. *NJAS - Wageningen Journal of Life Sciences*. 48(3): 213-236.

Van Harreveld, F., van der Pligt, J., de Vries, N.K. and Andreas, S. (2000) The structure of attitudes: attribute importance, accessibility, and judgement. *British. Journal of Social Psychology*. 39:363-380

van Kerkhoff, L., Lebel, L., (2006). Linking knowledge and action for sustainable development. Annu. Rev. Env. Resour. 31, 445e477.

Vanlauwe, B., Coyne, D., Gockowski, J., Hauser, S., Huising, J., Masso, C., and Van Asten, P. (2014). Sustainable intensification and the African smallholder farmer. *Current Opinion in Environmental Sustainability*, *8*, 15-22.

van Vliet, N., Reenberg, A. and Rasmussen, L. V. (2013) Scientific documentation of crop land changes in the Sahel: A half empty box of knowledge to support policy? *Journal of Arid Environments*. 95: 1-13

Venkateswarlu B., Srinivasarao Ch., and Venkateswarlu J. (2013) Traditional Knowledge for Sustainable Management of Soils. **In,** Lal, R. and Stewart B.A. (eds.) *Principles of Sustainable Soil Management in Agroecosysems.* Taylor & Francis Group: 303-335.

Vidal, L.-A., Marle, F. and Bocquet, J.-C. (2011) Using a Delphi process and the Analytic Hierarchy Process (AHP) to evaluate the complexity of projects. *Expert Systems with Applications*. 38(5): 5388-5405

Vosti, S. A. and Reardon, T. (1997a) Introduction: The Critical Triangle of Links among Sustainability, Growth, and Poverty Alleviation. **In**, Vosti, S. A. and Thomas, R. (eds.) *Sustainability, Growth, and Poverty Alleviation: A Policy and Agroecological Perspective.* The Johns Hopkins University Press: 1-15.

Vosti, S. A. and Reardon, T. (eds.) (1997b) *Sustainability, Growth, and Poverty Alleviation: A Policy and Agroecological Perspective.* The Johns Hopkins University Press.

Walkenhorst, P. (2007) *Distortions to Agricultural Incentives in Nigeria*. [online] World Bank. Available from: https://mpra.ub.uni-muenchen.de/10055/2/MPRA_paper_10055.pdf [Date accessed: 12/04/2017]

Walker, B., S. Carpenter, J. Anderies, N. Abel, G. Cumming, M. Janssen, L. Lebel, J. Norberg, G. D. Peterson, and R. Pritchard. (2002) Resilience management in social-ecological systems: a working hypothesis for a participatory approach. Conservation Ecology 6(1): 14. [online] URL: http://www.consecol.org/vol6/iss1/art14.

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004) Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society, 9*(2), [5].

Walker, J. and Cooper, M. (2011) Genealogies of resilience: From systems ecology to the political economy of crisis adaptation. *Security Dialogue*. 42(2): 143-160

Wallace, T. (1981) The Challenge of Food: Nigeria's Approach to Agriculture 1975–80. *Canadian Journal of African Studies / Revue canadienne des études africaines*. 15(2): 239-258

Wani, S. P., Sreedevi, T. K., Rockstrom, J. and Ramakrishna, Y. S. (2009) Rainfed Agriculture-Past Trends and Future Prospects. **In**, Wani, S. P., Rockstrom, J. and Oweis. (eds.) *Rainfed Agriculture: Unlocking the Potential.* CAB International: 1-35

Ward, C., Torquebiau, R. and Xie, H. (2016) *Improved Agricultural Water Management for Africa's Drylands*. World Bank Studies. Washington, DC: World Bank. doi: 10.1596/978-1-4648-0832-6. License: Creative Commons Attribution CC BY 3.0 IGO

Warren A., Batterbury S., and Osbahr H. (2001) Sustainability and Sahelian soils: evidence from Niger. *The Geographical Journal*. 167(4): 324–341

Watson, J. E. M. (2014) Human Responses to Climate Change will Seriously Impact Biodiversity Conservation: It's Time We Start Planning for Them. *Conservation Letters*. 7(1): 1-2

Watts, M. (1983) Hazards and Crisis: A Political Economy of Drought and Famine in Northern Nigeria. *Antipode*. 15(1): 24-34.

WCED (World Commission on Environment and Development) (1987) *Our Common Future.* Oxford University Press

Weber, E. (1997) Perception and expectation of climate change: Precondition for economic and technological adaptation. **In**, Bazerman, M., Messick, D., Tenbrusel, A., Wade-Benzoni, K. (Eds.), Perception and Expectation of Climate Change: Precondition for Economic and Technological Adaptation. Psychological Perspectives to Environmental and Ethical Issues in Management. Jossey-Bass, San Francisco, pp. 314– 341.

Wentholt, M. T. A., Fischer, A. R. H., Rowe, G., Marvin, H. J. P. and Frewer, L. J. (2010) Effective identification and management of emerging food risks: Results of an international Delphi survey. *Food Control*. 21(12, Supplement): 1731-1738

Were, K., Gelaw, A. M. and Singh, B. R. (2016) Smart Strategies for Enhanced Agricultural Resilience and Food Security Under a Changing Climate in Sub-Saharan Africa. **In**, Lal , R., Kraybill , David, *et al.* (eds.) *Climate Change and Multi-Dimensional Sustainability in African Agriculture.* Springer International Publishing: 431-453

Wever, R., van Kuijk, J. and Boks, C. (2008) User-centred design for sustainable behaviour. *International Journal of Sustainable Engineering*. 1(1): 9-20

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D. and David, C. (2009) Agroecology as a science, a movement and a practice. A review. *Agronomy for Sustainable Development*. 29(4): 503-515

Whitfield, S. (2016) *Adapting to Climate Uncertainty in African Agriculture.* Routledge

Widmer, T., Hirschi C., Serdult U. and Vogeli C. (2008) Analysis with APES, the Actor Process Event Scheme. **In**, Bergman, M. M. (eds). *Advances in mixed methods research: Theories and applications*. London SAGE: 150-171

Wiebe K., (2003) Linking Land Quality, Agricultural Productivity, and Food Security. *Agricultural Economic Report AER823*. Washington, DC: USDA.

Wilhelmi, O. V. and Wilhite, D. A. (2002) Assessing Vulnerability to Agricultural Drought: A Nebraska Case Study. *Natural Hazards*. 25(1): 37-58

Wilson, T.D, Lindsey, S., and Schooler, T.Y. (2000) A model of dual attitudes. *Psychol. Rev. 107: 101-26*

Wittman, H., Desmarais, A. and Wiebe, N. (2010) The Origins and Potentials of Food Sovereignty. **In**, Wittman H., Desmarais A. and Wiebe N. (eds.) *Food Sovereignty: Reconnecting Food, Nature and Community*. Pambazuka Press: 1-14

World Bank (1992) *World Development Report: Development and the Environment*. International Bank for Reconstruction and Development/The World Bank.

World Bank (2003) *World Development Indicators* 2003, Washington, D.C., USA.

World Bank (2007) *World Development Report 2008: Agriculture for Development*, The International Bank for Reconstruction and Development / The World Bank, Washington, DC.

World Bank and UK-DFID (2007) Nigeria Competiveness and Growth: Country Economic Memorandum. World Bank, Washington D.C and United Kingdom Department for International Development. Report No. 36483-NG.

World Bank (2008) *World Development Report 2008*: Development and Agriculture. Washington, DC: The World Bank.

World Bank (2009) *World Development Report 2010*: Development and Climate Change. World Bank. Washington DC.

World Bank (2014) *Nigeria Agriculture Sector Development Policy Operation Report.* [online] Available from: http://wwwwds.worldbank.org/external/default/WDSContentServer/WDSP/AFR/2014/11/15/090224b08286198a/1_0/Rendered/PDF/Nigeria000Nige0Report000Sequence002.pdf. [Date 10/11/2015].

World Data Atlas (2017) *Nigeria Import Food imports, 1960-2015 - knoema.com.* [online] @knoema. Available from: https://knoema.com//atlas/Nigeria/topics/Foreign-Trade/Import/Food-imports [Date accessed: 22/05/2017]

Ye, L., and Van Ranst, E. (2009) Production scenarios and the effect of soil degradation on long-term food security in China. *Global Environmental Change*, 19, 464-481.

Yeo, A., Legard R., Keegan J., Ward K., Nicholls C.M. and Lewis J. (2014) In-Depth Interviews. **In**, Ritchie J., Lewis J., Nicholls C.M. and Ormston R. (eds.) *Qualitative Research Practice: a guide for social science students & researchers.* 2nd edn. London SAGE Publications Ltd. 177-210

Yin, R. K. (2014) *Case Study Research: Design and Methods.* 5th edn. SAGE Publications Ltd.

Yousuf, M. I. (2007) Using Experts' Opinions through Delphi technique. *Practical Assessment, research & Evaluation*. 12(4): 1-8

Zikmund, W.G and Babin, B.J. (2007) *Exploring Marketing Research* 9th edn, Thomson South-Western, OH, USA.

Zilberman, D., Kaplan S., Kim E., Sexton S., and Barrows G. (2014) Biotechnology and food security. *Journal of International Affairs,* Spring/Summer. 67(2).

Appendices

Appendix 1: Scientific review of GAPs and evidences.

GAP Code	Description/ Practice	Relevance to Climatic Zones	Impact on Production	Positive Impact on Environment	Negative Impact on Environment	Impact on Climate Change	Comments	Reference
C	**Cropland management**							
C1.	Improved crop varieties.	Dryland/ humid	-30% increase in output in large plots[1]. -Early maturing. -Moisture & nutrient efficiency. -Increased yield[6].			-Increased soil carbon storage[2]		Kidane (2005)[1]. In: FAO (2010)[2]. Follett et al. (2001)[3]. Beukes et al. (1999)[4]. Granatstein (1992)[5]. FAO (2009)[6].
C2.	Reduced/zero tillage/no tillage.	Dryland	-30% increase in output[1]. -10-56 % yield increase in soybean[7]. -30 % yield increase in maize[7].	Higher yields in the long run in areas requiring more soil moisture[6].	-$N_2$0 emissions may increase as soils may become more anaerobic leading to more N_2O production from denitrification[8]	-Improves organic carbon concentratio n from root biomass build up[6].		Kidane, (2005)[1]. In: FAO (2010)[2]. Knoop et al., (2012)[7]. FAO (2009)[6]. Freibauer *et al.* (2004)[8]

C3.	Agroforestry/ perennials.	Dryland	-Increase in crop yields by 56% for crops under tree canopies compared to those without Trees. -Improved nutrient availability[41.] -Improved soil fertility[10.]	-Erosion control[6,41.] -Wind protection[50]. -Carbon cycling[10]. -Reduced evaporation[10]. -Better rainfall management[10]	-Overuse of ecosystem services[10.]	-Improves Carbon storage[6] -In tropics, it sequesters 0.2-3.1 t C ha^{-1} $year^{-1}$[(11).]	-Less food in the interim if intensive cropping patterns are disrupted. -Competition could arise for light, water & nutrients with crops[50.]	Murphy, H.F. (1968)[9]. In: FAO (2010)[2]. Knoop et al., (2012)[7]. Granatstein (1992)[5]. FAO (2009)[6]. Mbow *et al.* (2014)[10.] (Lal, 1999b)[11.] Tilman *et al.* (2002)[41] (Creswell and Martin 1998)[50.]
C4.	Incorporation of residues.		-Increased yields from fertility improvements[4]	-Increased water holding capacity[4].	-Possible slight increase of N_2O emissions from organic material in soil which is a source of mineralisable N[12.]	-Improves organic carbon concentratio n from root biomass build up[6.]	-Trade-off in use for animal feed[6].	Beukes et al. (1999)[4]. FAO (2009)[6]. Smith et al. (2001)[12.]
C5.	Use of cover crops.		-Reduced nutrient leaching[6,41.] -Increased yield[44.]	-Minimize erosion[43].	-Reduced grazing land in an integrated system[6].	-Increased soil carbon storage[3] (see W6).		FAO (2004)[13.] FAO (2009)[6.] (Follett et al. 2001)[3]. Tilman *et al.* (2002)[41.] Nana et al. (2014)[43.]

								M'Biandoun et al. (2010)[44.]
C6.	Improved crop fallow rotations.	Drylands (General)	-Higher yields due to improved soil fertility[6.]		-Reduced cropping intensity. May affect food security of household in the interim[6.]	-Increased soil carbon storage[3]	Could be hindered due to shortage of land (Author).	FAO (2009)[6]. Follett et al. (2001)[3].
C7.	Live barriers/fences.	Drylands	-Improved yields[6].		Reduced arable land[6].			FAO (2009)[6].
C8.	Increased efficiency of N fertilizer/ manure.		-Higher yields[6].			Sequesters 0.1-0.3 t C ha^{-1} $year^{-1}$[(11).]		FAO (2009)[6]. (Lal, 1999b)[11].
C9.	Use of legumes in crop rotation.	Dry sub-humid	-High yields due to increased N in soil[6] -*Vigna unguiculata*, *Arachis hypogea*-sorghum rotations gave 50-300 % yield increase in sub-humid area of Burkina Faso[46.]	-Slow-release formulations of N can help reduce leaching and N losses[5].			-Reduced cropping intensity might affect short term household food security[6].	-Granatstein (1992)[5]. -FAO (2009)[6]. -Bado *et al.* (2011)[46].
C10.	Timing of tillage		-For moisture retention[5].				Land should be tilled/ ploughed/	Granatstein (1992)[5].

							Harrowed (without moldboard) after harvest against next season to avoid further crusting[5]	
C11.	Depth of ploughing						-Deep ploughing (5-8 inches) in semi-arid climates helps in developing large moisture reservoir[5].	Granatstein (1992)[5].
C12.	Conservation agriculture	Arid/semi-arid	Increased crop yield & food production[6]			Sequesters 0.15-0.3 t C ha^{-1} $year^{-1}$(15).		Lal, (1999a)[15]. FAO (2009)[6]
W	**Water management**	Global drylands				-In drylands, it sequesters 0.05-0.1 t C ha^{-1} $year^{-1}$(11).		(Lal, 1999b)[11].
	Irrigation		-Higher yields[6].	-Greater land use intensity[6].	-CO_2 carbon cost of pumping water could exceed carbon sequestration benefits[16].	-Improves organic carbon concentration from root biomass build up[6].		FAO (2009)[6]. (Schlesinger, 1999)[16].
W1.	Spate irrigation	Semi-arid	-Wheat yield increased from 4-13 ton ha^{-1}, barley from 7-26 ton ha^{-1}, teff from 3-6 ton ha^{-1} & maize	-Flood control[7]. -Erosion control[7]. -Water infiltration[7].			-Good for midland & low land areas[7].	Knoop et al. (2012)[7]. Spate irrigation network, (2010)[17].

			from 8-32 ton $ha^{-1(17)}$.					
W2.	Pitcher irrigation & manure application & mulching	Dryland	-203 % increase in yield & 4.19 times water efficiency than can irrigation[18].					Pachpute, (2010)[18].
W3.	Bunds (contour bunds). Soil bunds, stone bunds, tied ridges E.g. Fanya juu (throw up in Kiswahili).	Semi-arid/arid	-Increased yields[6]. -17% increase in soil moisture[7]. -14 - 180% increase in fodder Production[7]	-Control erosion[7]. -Enhance infiltration[7]. -Soil conservation. -Minimize loss of top soil.	-Low yield in extreme high rainfall conditions[6]. -Reduction of arable area[7].	-Improves organic carbon concentration from root biomass build up[6].	Good for sloppy areas/hillsides & rainfall deficient areas[7].	Knoop et al., (2012)[7]. Granatstein (1992)[5]. FAO (2009)[6].
W4.	Grass strips	Dry and other areas.	-20% Increase of production in 3 years[7]	-Reduced runoff & erosion[7,19]. -Increased water absorption & soil fertility maintenance[19]	-Grass strips take up land, which cannot be used for other purposes[7].		Good for gentle & steep slopes[7].	Bayala et al. (2012)[19]. Granatstein (1992)[5]. Knoop et al., (2012)[7].
W5.	Improved Plant density	Dryland	20 percent increase in yield[23].	Water use efficiency				Reddy and Kidane (1993)[23]. **In**: FAO (2010)[2].
W6.	Mulching	Dryland	-Increased yield by 30% compared	-Reduced water loss	-Dead vegetation can breed plant	-Sequesters 0.05-0.1 t C ha^{-1} $year^{-1(11)}$.	Stubble mulch should be used in the rainy season or when nitrogen is	FAO, (2010)[2]. [Adapted from Knoop et al. 2012][7].

			without mulching[49.] -Using white plastic mulch, yield from whiteyam increased by 34%[7.] -Cassava using white & black plastic mulch yield was 90% and 38.5% respectively[7]. -Cocoyam 72 % using black plastic mulch[7].	from evapotranspiration[24]. -Reduced weed growth[7]. -Protect against heat & cold & add soil Nutrients[7]. -Reduces soil temperature & surface wind speed by 99 %[24,34]. -Conserves soil[24]. -Improves soil ecology[24].	diseases, insects & rodents[50.] -Stubble mulch depletes soil Nitrogen temporarily in dry season due to slowed decomposition[50]. -Low yields in high rainfall areas due to water logging caused by reduced evaporation[45]		not a limiting nutirent[50.]	Granatstein (1992)[5]. Erenstein (2003)[24.]. (Lal, 1999b)[11.]. Rusinamhodzi *et al.* (2011)[45]. Kidane et al. (2010)[49.] Sharma and Singh (2013)[34.] (Creswell and Martin 1998)[50.]
W7.	Zai Technique (demi-lunes)	Dry areas	-Increase production by about 500%[25]. -In combination with additions of nitrogen, increased potato yields 500-2000%; bean yields increased by 250%[27].	-Soil & water conservation[25.] -Restoration of degraded land and eroded soils[25]. -Slows run off[25]. -Improved soil structure[25]				(World Bank, 2005)[25.] In: AGRA, (2014)[26.] (Amede *et al.*, 2011)[27.] In: AGRA, (2014)[26.] Ouattara et al., (1999)[28.] Bayala et al. (2012)[19.]

			-Increased yield in millet (35-220 %).					
W8.	Double dug beds	Dry areas	In Machakos, Kenya 2,018 kg/ha was recorded under conventional tillage & 3,745 kg/ha under double dug beds[7] -Increase crop production[7] -Reduced evaporation[29]				In Nyeri, Kenya 8,331 kg/ha was recorded under conventional and 6,707 kg/ha was recorded under double dug bed[29]	(Source: Nandwa et al., (2000)[29]. In: Knoop et al., (2012)[7].
W9.	Tied ridges water harvesting (water conservation)	Semi-arid/arid	-Increase of 50-100% grain & 80% straw yield compared to planting in flat seedbed[2].	Water retention/ erosion control[7]			Good in degraded hillsides[2] -Increased crop production[7].	FAO (2010)[2]. Knoop et al., (2012)[7].
W10.	Terraces (conservation bench terraces)	Arid areas	-197 % internal rate of return. -Higher yields from reduced soil & water erosion[6].	-Store water, reducing runoff & trapping sediment -Prevent soil & water erosion[7]. -Improved soil quality.	-Reduction of arable area[6,7]. -They allow generation of additional runoff.		-Good for sloppy areas.	FAO (2009)[6]. Knoop et al., (2012)[7].

W11.	Conservation tillage	Arid areas	Light tillage helps in increasing water absorption[5].			Sequesters 0.1-0.2 t C ha^{-1} $year^{-1}$[(11)].	Make seed beds[5]	Granatstein (1992)[5]. (Lal, 1999b)[11].
W12.	Composting (Heap method)	Dry and other areas	In Machakos 2,018 kg/ha was recorded and in Nyeri 2,449 kg/ha under manure plus DAP while under compost; 2,449 kg/ha & 5,071 kg/ha was recorded in Machakos & Nyeri respectively[7].		N_2O emissions during composting process[8]	(See C8).	This is a hidden water harvesting technique[7].	Knoop *et al.,* (2012)[7]. Freibauer *et al.* (2004)[8].
W13.	Water harvesting ponds	Drylands	-Makes water available for production during dry spells in the rainy season, & for a few months after the rains cease[7].	Erosion control[7].	Could form breeding ground for vectors of disease & poor quality water[7].			Knoop et al. (2012)[7].
W14.	Harvesting water from roofs	Drylands	Yield 24,700 litres from a surface area of $100m^2$ with a	-Reuse[7]			Very useful for household use in drylands[7].	Knoop et al. (2012)[7].

			seasonal rainfall of 260 mm[7].					
W15.	Contour Infiltration ditches	Arid /semi-arid		-Stops runoff & soil erosion[34].		Increased Carbon storage[6].		Sharma and Singh (2013)[34]. FAO (2009)[6].
W16.	Flood recession farming	Arid/semi-arid	-Increased crop production & grazing[7]	Water recharge, reuse, & flow regulation[7]				Knoop et al., (2012)[7].
D	**Degraded lands restoration**							
D1.	Re-vegetation		-Improved yields when crops are sown in the medium to long term[6]. -Improved yields on adjacent land due to soil, wind & or water erosion control[6].			Increased Carbon storage[6].		FAO (2009)[6].
D2.	Organic Nutrient amendments (manures, bio-solids, compost).		-Improved yields in the medium-long term[6].	Improves water holding capacity of soils[6].	Increased emissions due to transport of these inputs from source to farm[35].	Increased Carbon storage[6]. (See C8).		FAO (2009)[6]. Smith and Smith (2000)[35].
D3.	Percolation ponds & contour trenches			They are useful in		Increased Carbon storage[6].		FAO (2009)[6].

				tackling runoffs[6].				
D4.	Tube recharge					Increased Carbon storage[6.]		(FAO 2009)[6.]
D5.	Subsurface dams			Erosion control[7]		Increased Carbon storage[6]	Practiced in Brazil	Knoop *et al.* (2012)[7]. FAO (2009)[6.]
D6.	Sand dams			Erosion control[6.]	-Obstruction of migrating species[7]	Increased Carbon storage[6.]		FAO (2009)[6.]
D7.	Nitrogen fixation by legumes			-Soil protection[34]. -Soil erosion control[34].				Sharma and Singh, (2013)[34].
D8.	Conservation agriculture practices		-Increased soil fertility & crop production[7]	-Water retention, infiltration, biodiversity conservation, pest & erosion control[7]		Increased Carbon storage[6.] (See C13.)		-FAO (2009)[6] Knoop *et al.* (2012)[7]
F	**Soil fertility Management**							
F1.	Ploughing-under 90 day old stylo green manure		-Increase of 1.7 ton ha^{-1} maize yield than control. -Cereal yield increases of 600-4100 kg ha^{-1}					-Ogbonna and Mabbaya, (1983)[36.] -Peoples and Herridge, (1990)[37.]

F2.	Integrated soil fertility & plant nutrient management		-Yield increases of 33–58 percent over a four-year period[47.] -Yield increases[48]			- Reduced onsite N_20 emission by reducing leaching and improving nitrogen use efficiency[6.] (See C8).		-Winterbottom *et al.* (2013)[47.] - Lipper et al. (2011)[38.] FAO (2009)[6] Øygard *et al.* 1999)[48.]
F3.	Fertilisation	Dry arid	-Restore soil fertility[41.] -Improved water productivity[42.]		-Increased N_2O emissions due to addition of extra reactive N to the soil[8.]			Freibauer *et al.* (2004)[8.] Tilman *et al.* (2002)[41.] Wani *et al.* (2009)[42.]
F4.	Intercropping legumes with other crops		(see C9)					
F5.	Use of cover crops		(see C5)					
P	**Pest & disease management**		-Split application of Nitrogen fertilizers[40.].					(Baig *et al.* 2013)[40.]

P1.	Crop rotation		-Maintains fertility and reduces soil erosion[34]. -Conserves moisture[41].	-Reduced use of pesticide[41.] -Removal of pathogen.		-Risk aversion.		Tilman *et al.* (2002)[41.] Sharma and Singh (2013)[34]. Granatstein (1992)[5].
P2.	Integrated Pest Management (IPM)			-Reduced number of pest[2]				FAO (2010)[2]
P3.	Pest-resistant crop varieties				Uncertified seeds could be a source of disease & pest[2]			FAO (2010)[2]
P4.	Destruction of diseased crop residue			Controls disease[5.]	Degrades air quality & reduces soil organic matter[5.]		Trade-off for mulching and animal feed (Author)	Granatstein (1992)[5].

References

AGRA (Alliance for a Green Revolution in Africa). (2014) Africa agriculture status report: Climate change and smallholder agriculture in sub-Saharan Africa. Nairobi, Kenya

Amede,T., S.Tarawali., and D.Peden (2011) Zai improves nutrient and water productivity in the Ethiopian Highlands (Special issue: Improving water productivity of crop –livestock systems in drought-proneregions). Experimental Agriculture, 47 (Suppl:1): 7-20

Bado, V., Sawadogo, A., Thio, B., Bationo, A., Traore, K. and Cescas, M. (2011) Nematode infestation and N-effect of legumes on soil and crop yields in legume-sorghum rotations. *Agricultural Sciences* 2, 49-55.

Baig, M. B., Shahid, S. A. and Straquadine, G. S. (2013) Making rainfed agriculture sustainable through environmental friendly technologies in Pakistan: A review. *International Soil and Water Conservation Research*. 1(2): 36-52

Bayala J., Sileshi G.W., Coe R., Kalinganire A., Tchoundjeu Z., Sinclair F., Garrity D. (2012) Cereal yield response to conservation agriculture practices in drylands of West Africa: A quantitative synthesis. *Journal of Arid Environments.* 78:13-25

Beukes, D.J., A.T.P. Bennie & M. Hensley, 1999. Optimizing of soil water use in the dry crop areas of South Africa. In: N. Van Duivenbooden, M. Pala, C. Studer & C.L. Bielders (Eds.), Efficient soil water use: the key to sustainable crop production in the dry areas of West Asia, and North and Sub-Saharan Africa. ICARDA, Aleppo/ICRISAT, Patancheru, pp. 165-191.

Creswell, R. and Martin, F. W. (1998) *Dryland Farming: Crops & Techniques for Arid Regions.* ECHO

Erenstein, O. (2003) Smallholder conservation farming in the tropics and sub-tropics: a guide to the development and dissemination of mulching with crop residues and cover crops. *Agriculture, Ecosystems and Environment*. (100): 17-37

FAO (2004) Good Agricultural Practices-a working concept. Background paper for the FAO Internal Workshop on Good Agricultural Practices. Rome, Italy. FAO GAP WORKING PAPER SERIES 5. Available at: http://www.fao.org/prods/gap/docs/pdf/5-gapworkingconceptpaperexternal.pdf. [Accessed on 18/11/15].

FAO, (2009) Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies. Rome.

FAO (2010) Good Agricultural Practices (GAP) on horticultural production for extension staff in Tanzania. Rome, Italy. FAO GAP WORKING PAPER SERIES 13. Available at: http://www.fao.org/search/en/?cx=018170620143701104933%3Aqq82jsfba7w&q=GAP+working+paper+series&cof=FORID%3A9&siteurl=www.fao.org%2Fabout%2Fen%2F&ref=w

ww.fao.org%2Fpublications%2Fsofi%2F2014%2Fen%2F&ss=9951j10542305j25. Accessed on 11/05/15.

Follett, R.F., Kimble, J.M., Lal R. (2001) *The potential of U.S. grazing lands to sequester soil carbon,* ***In:*** *The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect*, R.F. Follett, Kimble J.M., Lal R., Editor. 2001, Lewis Publishers: Boca Raton, Florida. p. 401-430.

Freibauer, A., Rounsevell, M. D. A., Smith, P. and Verhagen, J. (2004) Carbon sequestration in the agricultural soils of Europe. *Geoderma*. 122: 1-23

Granatstein, D. (1992) Dryland Farming in the Northwestern United States:A Nontechnical Overview. MISC0162, Washington State University Cooperative Extension, Pullman. 31 pp

Kidane, G., Dejene, A. and Malo, M. (2010) Agricultural based Livelihood Systems in Drylands in the Context of Climate Change: Inventory of Adaptation Practices and Technologies of Ethiopia. FAO, Rome Italy

Knoop, L., Sambalino, F. and Van Steenbergen, F. (2012) Securing Water and Land in the Tana Basin: a resource book for water managers and practitioners. Wageningen, The Netherlands: 3R Water Secretariat.

Lal, R. (1999a) Soil management and restoration for C sequestration to mitigate the accelerated greenhouse effect. Progress Environ. Sci. 1, 307– 326.

Lal, R. (1999b) Global carbon pools and fluxes and the impact of agricultural intensification and judicious land use. Prevention of Land Degradation, Enhancement of Carbon Sequestration and Conservation of Biodiversity Through Land Use Change and Sustainable Land Management with a Focus on Latin America and the Caribbean. World Soil Resources Report 86. FAO, Rome, pp. 45– 52.

M'Biandoun, M., Dongmo, A.L. and Balarabe, O. (2010) Culture systems on vegetation cover in Central Africa: technical conditions and for its socioeconomic development. L. Seiny-Boukar, P. BOUMARD. Savannas in African development: innovating to last Apr 2009, Garoua, Cameroon. CIRAD, 10 p.

Mbow, C., Smith, P., Skole, D., Duguma, L. and Bustamante, M. (2014) Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability*. 6: 8-14

Nana, P. D, Dugue, P., Mkomwa, S., Da Sansan, J. B., Guillaume, E, Bougoum, H., Zerbo, I. Ganou, S. Andrieu, N. and Douzet, J. (2014) Conservation Agriculture in West and Central Africa. **In**, Jat R.A. Sahrawat K.L and Kassam A.H. (eds.) *Conservation Agriculture: Global Prospects and Challenges*. CAB International: 311-338

Ogbonna, C. K. C and Mabbaya B.B. 1983. Effects of incorporation of 90-day-old stylo as GM on the yield of corn and soil properties. Phillip. J. Crop Sci. 8: 129-132.

Ouattara, B., V. Hien & F. Lompo, 1999. Development of water management technologies for rainfed crops in Burkina Faso. In: N. Van Duivenbooden, M. Pala, C. Studer & C.L. Bielders (Eds.), Efficient soil water use: the key to sustainable crop production in the dry areas of West Asia, and North and Sub-Saharan Africa. ICARDA, Aleppo/ICRISAT, Patancheru, pp. 265-281.

Øygard, R., Vedeld, T. and Aune, J. (1999) *Good Practices in Drylands Management.* The World Bank

Pachpute, J.S. 2010. A package of water management practices for sustainable growth and improved production of vegetable crop in labour and water scarce Sub-Saharan Africa. *Agricultural Water Management* 97 (2010) 1251–1258

Peoples, M. B, and Herridge, D. F (1990) Nitrogen fixation by legumes in tropical and subtropical agriculture. *Adv. Agron.* 44: 155-223.

Rusinamhozi, L., Corbeels, M., van WIjk, M.T., Rufino, M.C., Nyamangara, J. and Giller, K.E. (2011) A meta-analysis of long-term effects of conservation agriculture practices on maize grain yield under rain-fed conditions: lessons from southern Africa. *Agronomy for Sustainable Development.* 31: 657-673.

Schlesinger, W. H. (1999) Carbon sequestration in soils. Science 284, 2095.

Sharma, N. K. and Singh, R. J. (2013) Agronomic practices for Erosion Control. *Popular Kheti.*1(30):57-60.

Smith, P., and Smith, T. J. F. (2000) Transport carbon costs do not negate the benefits of agricultural carbon mitigation options. *Ecol. Lett.* 3: 379– 381.

Smith, P., Goulding, K.W., Smith, K.A., Powlson, D.S., Smith, J.U., Falloon, P.D., Coleman, K. (2001) Enhancing the carbon sink in European agricultural soils: Including trace gas fluxes in estimates of carbon mitigation potential. Nutr. Cycl. Agroecosyst. 60: 237– 252.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R. and Polasky, S. (2002) Agricultural sustainability and intensive production practices. *NATURE*. 418: 671-677

Wani S.P., Sreedevi T.K., Rockström J., and Ramakrishna (2009) Rainfed Adriculture-Past trends and Future Prospects. **In**, S.P Wani, J. Rockström and T Oweis (eds.) *Rainfed Agriculture: Unlocking the Potential.* CAB International: 1-35

Winterbottom, R., Reij C., Garrity D., Glover J., Hellums D., McGahuey M. and Scherr S. (2013) "Improving Land and Water Management." Working Paper, Installment 4 of *Creating a Sustainable Food Future.* Washington, DC: World Resources Institute. Accessible at: http://www.worldresourcesreport.org

World Bank (2005). IK Notes no.80. Burkina Faso: the Zai technique and enhanced agricultural productivity

Appendix 2. Family size and labour bought–in: A case of two farming households in Kofa and Zango communities.

Box 1. Family size and labour bought–in: A case of two farming households in Kofa and Zango communities.

Farmer 35 in Kofa is a female farmer aged between 51-60 years, a widow with five children and no formal education. Only one of her children has primary education. In terms of food security, the household consumes 3 meals per day with two meals containing protein. House type is mud brick wall with tin roof which is suitable for rain water harvesting. Household water is collected presently from a 12 metre distance well by the household head herself as she only lives with few of her grown up children who engage in other ventures. Mobile phone is the only capital asset owned by the household with few livestock (10 sheep, 6 goats and 4 chickens) which serve as a form of insurance against crop failure and a source of manure for the fields. The household also rely on external input such as improved seeds, inorganic fertilizers and pesticides which is easily available but expensive. The main crops grown by the household are rice, sorghum, maize and soybean on a two and half hectare land with most of the land devoted to commercial soybean production using bought-in labour due to small family size and large plots. The farmer works full time on her farm 6 hours a day with one of her children helping on part time basis for 2 hours a day. Land is in 3 places (fragments) with no title deeds. Source of production water is rainfall with no form of irrigation. No form of extension has ever been received by this farmer yet she manages average yield using mixed system of cropping. Other source of income to the household is from the sales of tree crops (mango and baobab) to the nearby Kofa market which is less than 2 Kilometres and takes less than an hour to walk with few produce to sell. For bigger sales, customers come to her house to purchase. No form of vegetable is grown by the farmer.

The second farmer, Farmer 48 in Zango is a male farmer within age range of 51-60 with 2 wives and 11 children within the age range of 5-30 years old. The farmer has no formal education with 9 of his children attending school at primary to tertiary levels. In the area of food security, the household consumes 3 meals per day with one meal containing protein. House type is mud brick wall with mud roof which is not ideal for collecting rain water in dry Zango community. Household water is collected from local standpipe 20 metres away by both male and female children. Bicycle, plough, radio and mobile phone are the capital assets owned by household with some livestock (18 cattle, 10 sheep and 16 chickens) which serve as insurance against crop failure, hiring animal mounted plough for farm cultivation, source of milk for sale and manure for the farm. Household has access to only seeds input with fertilizers and pesticides inaccessible due to cost (expensive). Crops grown include millet, cowpea, sesame for sale and consumption, groundnuts for sale and sorghum for consumption using labour bought-in as labour is not enough with 4 household members working 6 hours full time and 2 working 3 hours part-time while children go to school and no member has secondary employment. Household has one and half hectares in four places with no land title and depend only on rain-fed agriculture practicing mixed farming with some extension support.

The fact that farmer 48 had more children, he had no labour advantage over farmer 35 in not buying-in labour as his children go to school and do not work on farm.

Appendix 3

Baseline survey report to communities

Baseline survey report

Zango & Kofa communities

Author: Patrick Nugun Jellason
Royal Agricultural University, Cirencester
Stroud Road
GL7 6JS
Nugunpatrick.jellason@student.rau.ac.uk
+447501040466; +2348035335456.
08/03/2016.

Introduction

- A baseline survey was carried out in Zango & Kofa from June to July, 2015 as part of a PhD Research on assessing current practices and perceptions of North West Nigerian dryland farmers about environmental challenges in order to understand how resilience to adverse environmental challenges can be enhanced using Good Agricultural practices.
- Stakeholders who comprise research institutions and government extension providers were also engaged on current research and extension around dryland agriculture.

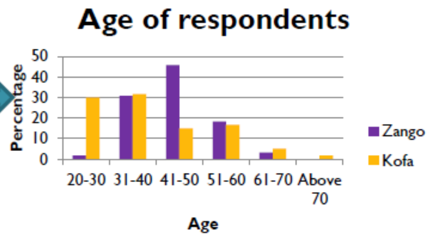
Methodology

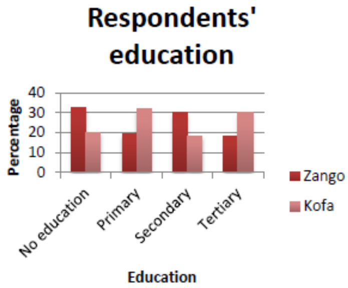
- **DATA COLLECTION**
- Zango and Kofa communities were purposively selected to reflect the dry conditions needed for the study.
- Data were collected using a modified household livelihood survey questionnaire in the first of three field visits. 120 households in Zango and 60 in Kofa were surveyed on topics including socio-economic conditions, current practices, perceptions of environmental challenges, adaptation strategies and availability of extension.
- Five stakeholders who comprise research institutions and government extension providers were also engaged using a separate semi-structured interview tool on current research and extension around dryland agriculture.

RESULTS

Demographic characteristics of the study communities

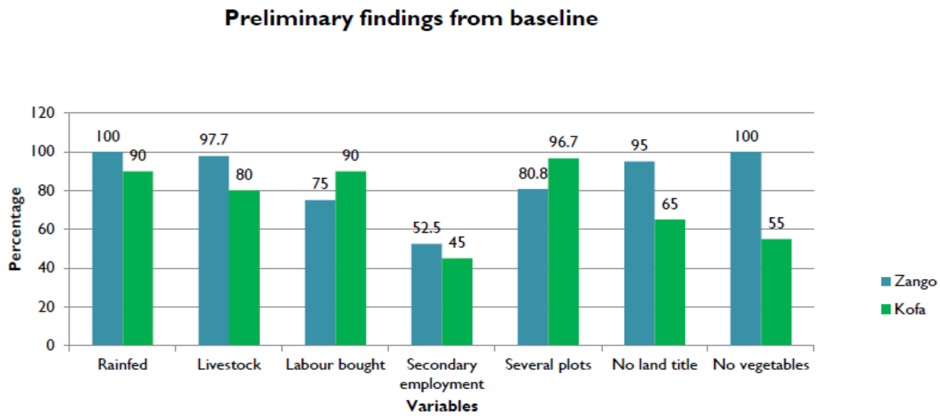
Demographic characteristics of respondents	Zango (%) n=120	Kofa (%) n=60
Age		
20-30	1.7	30.0
31-40	30.8	31.7
41-50	45.8	15.0
51-60	18.3	16.7
61-70	3.3	5.0
Above 70	-	1.7
Total	100.0	100.0
Gender		
Male	83.3	95.0
Female	16.7	5.0
Total	100.0	100.0
Marital status		
Single	1.7	10.0
Married	95.0	88.3
Widowed	3.3	1.7
Total	100.0	100.0
No. of children		
0	.8	13.3
1-5	31.1	53.3
6-10	44.5	21.7
11-15	21.0	8.3
16-20	1.7	0
Above 20	.8	3.3
Total	100.0	100.0
Highest education		
No education	32.5	20.0
Primary	19.2	31.7
Secondary	30.0	18.3
Tertiary	18.3	30.0
Total	100.0	100.0





Source: Field survey, 2015

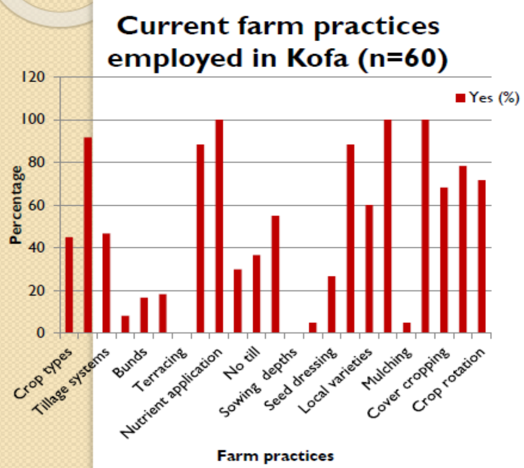
Some baseline results

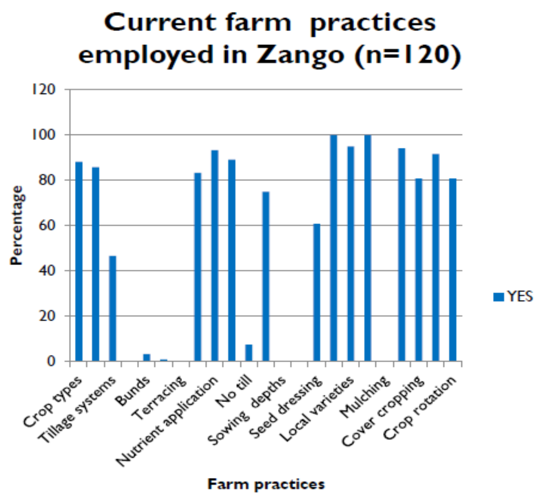


Some findings from stakeholder engagement

- Soil degradation was ranked as the most important environmental concern
- Drought as the second most important
- Pest & disease as the third most important
- Workload (1 extension officer:100-1000 farmers)
- Poor funding of extension
- Inadequate and lack of up to date training

Current practices





Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Researcher & an indigenous farmer

Researcher training field assistants

Tilled plot with some trees on sight

Researcher using the animal plough

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Researcher interviewing some of the female farmers

Manure spread on field prior to ploughing & crop planting

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

Some materials have been removed due to 3rd party copyright. The unabridged version can be viewed in Lancester Library - Coventry University.

one of the enthusiastic respondents

A female respondent in her animal pen that supply manure for her fields

Conclusions and way forward

- In attempting to improve the sustainability of drylands agriculture in sub-Saharan Africa and after collected baseline data on the current position of farmers and practices; perceptions and adaptation strategies to environmental challenges in the drylands of Nigeria, this research will proceed with developing farmer guidance based on the identified poor practices for water, soil fertility management and degraded land restoration in the two drylands study communities of Zango and Kofa.
- The findings from this baseline will inform the next field visit that will take place in April 2016 where in a participatory approach, 25 lead farmers will be selected alongside extension agents to be trained on the above. Focus groups followed by one on one interview will be carried out to probe further on the initial findings and to collect qualitative responses of the respondents selected for the second visit. It is expected that (and will be encouraged) the trained farmers will share the knowledge gained in the training with other farmers in a cluster.
- Farmer field schools and demonstration plots will be part of the intensive training with the farmers in order to enhance learning and uptake. Extension training is also envisaged to support learning in the absence of the researcher for sustainability of the project.
- Women participation is proposed to be encouraged in the area of vegetable production while exploring small scale irrigation for household food security.

Data analysis

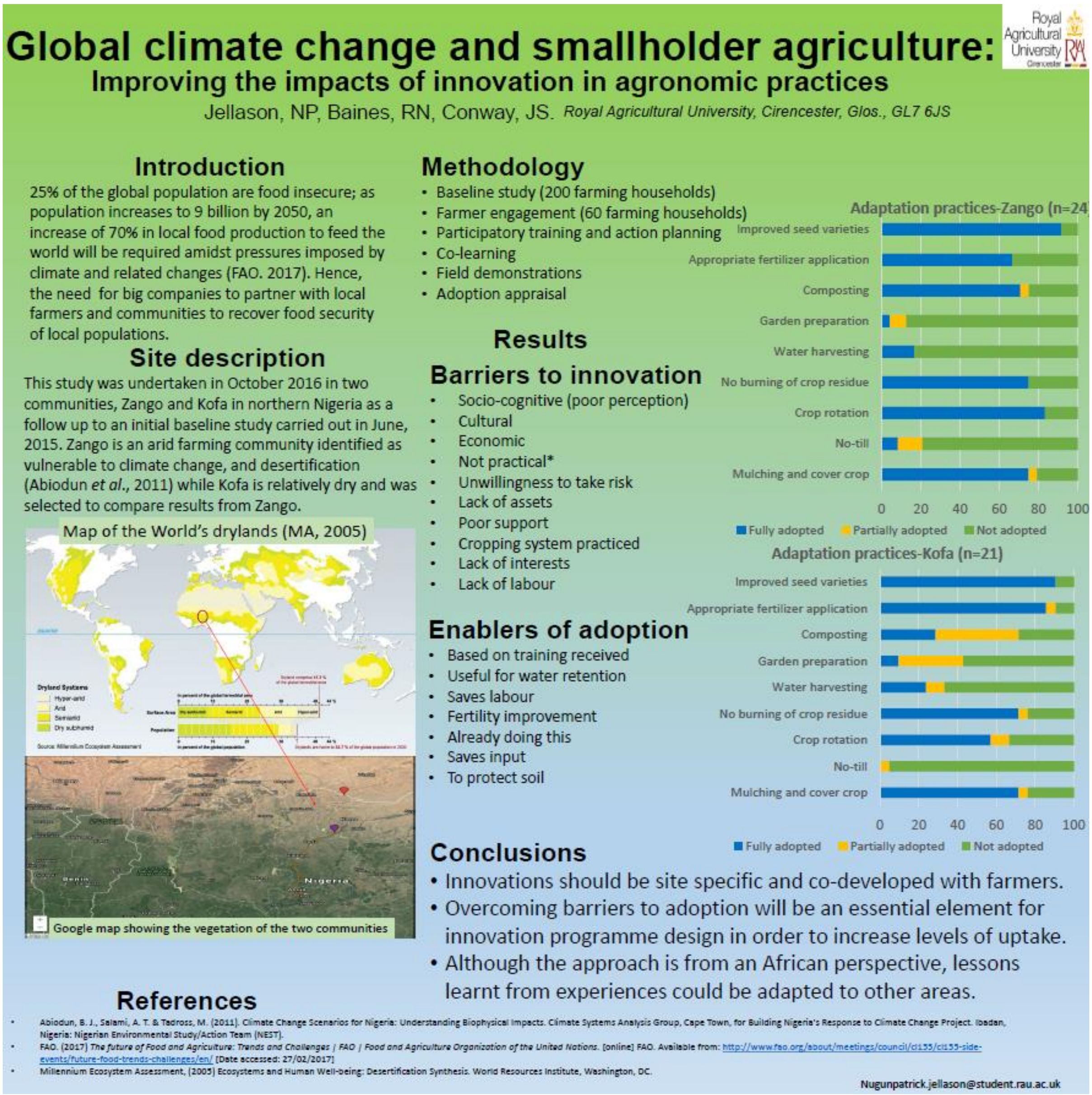
- Data collected was entered into SPSS software version 22, coded and cleaned before analysis.
- Data were analysed using tables, graphs, charts and narrations to describe the current position of agriculture in the study communities.
- Some results have been selected and presented in this report as follows:

Appendix 4

a. Conferences and events attended

Date	Event	Location	Author's contribution
18/06/2015	Nigerian Research Day	University of Birmingham	Audience
25/09/2015	Montpellier Panel Report: Agri4impact	Institute for Government, London	Audience
13/10/2015	End of first year review	Royal Agricultural University, Cirencester	Oral Presentation
13-14/01/2016	Postgraduate Winter School 2016, organized by the Countryside and Community Institute (CCRI)	University of Gloucestershire in association with RGS-IBG Rural Geography Research Group & the Rural Services Network	Audience
02/02/2016	Launch Time University-Wide Seminar	Royal Agricultural University, Cirencester	Oral Presentation
04/02/2016 Also in March & May, 2016	Resilience Reading group	University of Gloucestershire, Oxstalls Campus	Contributor
23/06/2016	Nigerian research Day Workshop	Oxford Department for International Development University of Oxford, UK	Oral Presentation
08/07/2016	Drylands Research Afternoon: Talk on a newly published book on "The End of Desertification: Disputing Environmental Change in the Drylands".	Goodenough College, Mecklenburgh square, London.	Audience
30/08-02/09/2016	2016 Annual International Conference	Royal Geographical Society with IBG, London	Two Oral Presentations
07/12/2016	End of second year review	Royal Agricultural University, Cirencester	Oral Presentation
12/01/2017	CCRI Winter School for Post-graduate Researchers	University of Gloucestershire, Oxstalls Campus	Oral Presentation
26-28/03/2017	The 2nd Agriculture and Climate Change Conference 2017- Elsevier	Sitges, Spain.	Poster Presentation
03/05/2017	The 8th Annual SIID PGR Conference	University of Sheffield	Oral Presentation
27/06/2017	The 2nd International Conference on Food Security & Sustainability	San Diego, USA	Oral Presentation

b. Conference poster



Appendix 5

a. Baseline survey Questionnaire

ROYAL AGRICULTURAL UNIVERSITY, CIRENCESTER, GLOUCESTERSHIRE-UK

Farmers Interview Questionnaire

To be completed by Interviewer *Please complete before the Interview*		**To be completed by Team Leader:**
0.1	*Interviewer Name:* **a. |__|__|__|__|__|__|__|__|__|__|** **b. |__|__|__|__|__|__|__|__|__|__|**	**0.4 – Date: |__|__| / |__|__| / 2013** **Day Month** **0.5- Leader's Name:** **|__|__|__|__|__|__|__|__|__|__|**
0.2	**Date: |__|__| / |__|__| / |__|__|__|__|** *Day Month Year*	**Remarks:** ________________
0.3	**Interview Location:__________________** **GPS Coordinates:________________________**	________________ ________________ ________________

Please read / explain to the respondent the following consent information:

My name is Nugun P. Jellason, I am part of an assessment team that is currently reviewing the **Effects of Environmental Challenges & Risk Management Strategies in the Drylands of Nigeria** & to determine how to achieve greater sustainability in food security while exploring opportunities for greenhouse gases mitigation in the dryland farming..

We are requesting your contribution to enable us to gain a deeper understanding of the constraints and opportunities in relation to your farming activities/household income.

Our discussion is expected to take between 45 minutes - 1 hour and I would also like to visit your plots to discuss how you farm and take some pictures if that is possible.

Any information that you provide will be confidential and will not be disclosed to other people. Your participation is voluntary and you can choose not to answer any or all of the questions if you wish; however we hope you will participate since your views are important.

Do you have any questions?

Yes ☐ No ☐

If you are happy to proceed with this interview today, can you sign here:

Interviewee Signature:
…………………………………..

Signature of Interviewer:
………………………………..

Date: ……………………………….

May I begin the interview now?

Signature of Team Leader:

To be completed by Data Entry

0.6 – Date: |__|__| / |__|__| / 2013
Day Month

0.7- |__|__|__|__|__|__|__|__|__|__|
Name of data entry operator

Remarks:

Signature of data entry:

<table>
<tr><th>Question No</th><th>Question</th><th colspan="6">Response</th></tr>
<tr><td>Q1</td><td>Name of Respondent</td><td colspan="6"></td></tr>
<tr><td rowspan="2">Q2</td><td rowspan="2">Are you the household Head?</td><td>Yes</td><td></td><td colspan="4" rowspan="2">Q3 If not what is your relationship to the HH? (e.g. wife, son, brother)</td></tr>
<tr><td>No</td><td></td></tr>
<tr><td>Q4</td><td>Respondent Mobile Number</td><td colspan="6"></td></tr>
<tr><td>Q5a

Q5b</td><td>Name of Respondent Community

Respondent – tribe/religion</td><td colspan="6">Tribe ……………………Religion/Denomination ………………..</td></tr>
<tr><td>Q6</td><td>Respondent – Sex</td><td>Male</td><td></td><td colspan="2">Female</td><td colspan="2"></td></tr>
<tr><td>Q7a</td><td>Respondent - Marital Status</td><td colspan="6">Single [ ], Married [ ], Widow [ ], Widower [ ]</td></tr>
<tr><td>Q7b</td><td>Respondent's number of spouses</td><td>Q7c.</td><td colspan="3">Respondents Total Number of Children</td><td colspan="2"></td></tr>
<tr><td rowspan="9">Q8a</td><td rowspan="9">a) Respondent Age (tick appropriate response)

b) Family age/gender</td><td rowspan="2">Respondent age</td><td rowspan="2">Tick</td><td rowspan="2">Family age</td><td rowspan="2">No</td><td colspan="2">Gender</td></tr>
<tr><td>M</td><td>F</td></tr>
<tr><td>Less than 20 Years</td><td></td><td>Less than 5 yrs</td><td></td><td></td><td></td></tr>
<tr><td>20 – 30 Years</td><td></td><td>5 - 10 years</td><td></td><td></td><td></td></tr>
<tr><td>31 – 40 Years</td><td></td><td>11 – 20 years</td><td></td><td></td><td></td></tr>
<tr><td>41 – 50 Years</td><td></td><td>21 – 30 Years</td><td></td><td></td><td></td></tr>
<tr><td>51 – 60 Years</td><td></td><td>31 – 40 Years</td><td></td><td></td><td></td></tr>
<tr><td>61 – 70 Years</td><td></td><td>41 – 50 Years</td><td></td><td></td><td></td></tr>
<tr><td>Above 70 Years
Doesn't Know</td><td></td><td>Above 50 years
Doesn't know</td><td></td><td></td><td></td></tr>
<tr><td rowspan="8">Q8b</td><td rowspan="8">Spouse Age</td><td>Less than 20 Years</td><td></td><td rowspan="8"></td><td rowspan="8"></td><td colspan="2" rowspan="8"></td></tr>
<tr><td>20 – 30 Years</td><td></td></tr>
<tr><td>31 – 40 Years</td><td></td></tr>
<tr><td>41 – 50 Years</td><td></td></tr>
<tr><td>51 – 60 Years</td><td></td></tr>
<tr><td>61 – 70 Years</td><td></td></tr>
<tr><td>Above 70 Years</td><td></td></tr>
<tr><td>Doesn't Know</td><td></td></tr>
<tr><td rowspan="6">Q9</td><td rowspan="6">a) Respondent Highest Education Level
b) Family Education</td><td rowspan="2">a) Respondent</td><td rowspan="2">Tick</td><td rowspan="2">b) No of family</td><td colspan="3">Gender</td></tr>
<tr><td>M</td><td colspan="2">F</td></tr>
<tr><td>Primary</td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Secondary</td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Tertiary</td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>No Education</td><td></td><td></td><td></td><td colspan="2"></td></tr>
</table>

Q10	Can you read and write?	**Read**		**Q11** How about other members of HH?		
		Write		**read (number)**		
				write (number)		

Q12		**1 meal**	**2 meals**	**3 meals**	**More**
	a) How many meals does your household normally consume in a day? b) How many meals each day contain protein (meat, fish, beans)				

Q13	**Household Assets** Describe the build of your house a) What type of walls? b) What type of roof? c) How many rooms d) House water supply *Take photo of house if possible*	Mud brick [ ] Brick [ ] Wood [ ] other (state) ………… Tiles [ ] Tin [ ] Wood/thatch [ ] other ……………… State room number ……. In house [ ] Local standpipe [ ] Collect from well [ ] Collect from river/lake/stream [ ] Who collects? [ ] Others (specify)…………………– Distance…………….	
Q14	Tick the assets that are owned by the household	Vehicle	Radio
		Cart	Mobile Phone
		Bicycle	Television
		Plough	Solar Panel
		Irrigation equipment	Other (state)

Q15	**Main Livestock Assets**	**No**	**Yes**	**If Yes – how many?**
	Do you own any cattle?			
	Do you own any sheep?			
	Do you own any goats?			
	Do you own any pigs?			
	Do you own any chickens?			
	Do you own any other livestock?			

Q16	**Please indicate the five most important crops that you grow?**	Crop	% Home Consumption	% to market

Q17	**Labour** How many of the household work on the farm?	Full time (hours)		Part time (hours)	
Q18	Do you have enough labour to facilitate crop and livestock production in your household	YES		NO	
Q19	If NO, why is labour a constraint (explain)				
Q20	Do you buy in labour or rent out family members to other farms?	Labour bought in [ ] days per month; Cost per day [ ] Labour rented out [ ] days per month; Cost per day [ ]			
Q21	Do any family members have secondary (non-farm) employment?	Yes [ ] No [ ]	If yes: who and what type of employment:		
Q22	**Land** What is the size of your total production land? *(use appropriate measures community are familiar with).* *If uncertain then pace out when visiting plots*	Less than 20m^2 (4m x 4m)			
		20m^2 to 50m^2 (up to 6m x 6m)			
		50m^2 to 100m^2 (up to 10m x 10m)			
		100m^2 to 400m^2 (up to 20m x 20m)			
		Larger – state size			
		Is your land in 1 or several plots	1 plot [ ] several [no …….]		
Q23	Do you have title deeds for the land?	YES [ ] NO [ ] Some with title deeds [ ]			

Q24	**Water** Do you have a water source for your crop production activities and livestock?	YES		NO (rain fed) [Go to Q30]	
Q25	If Yes what is your source of water?	River		Dam	
		Stream		Well	
		Borehole		Other	
Q26	Does this source provide you with sufficient water for crop production throughout the year?	YES		NO	No. of months dry [ ]
Q27	Do you have irrigation equipment for your crop production activities?	Yes		NO (Go to Q 30)	
Q28	Type of irrigation equipment	Shaduf		Sprinkler	
		Drip		Buckets	
		Other (specify)			

Q29	What is your preferred irrigation method?	
Q30	**Crop Inputs** a) Are the inputs required for crop production easily available to farmers in your community e.g. seeds, fertilisers and pesticides? b) If no, what are the main reasons?	Seeds Yes [ ] No [ ] Fertilisers Yes [ ] No [ ] Type: Pesticides Yes [ ] No [ ] Reasons:

Q31	What is the main challenge that you face to access crop production inputs?	Finance		quality of inputs	
		Distance from input markets		Other (specify)	

Q32	**Extension Support** Do you receive extension advice from a trained extension officer regularly?	YES		NO	
Q33	The extension officer that visits you – where are they from? (Take note of the extension officers name: …………………………………………………..	Government		Private Company	
		NGO		Other (specify)	
Q34	How often do you receive visits by an extension officer for technical support linked to your vegetable production activities?	Weekly		Every 5 - 8 months	
		Monthly		Once every year	
		Every 2 - 4 months		Never/rarely visited	
Q35	Are you satisfied by the technical support that you receive from extension officers?	Very happy [ ]	Happy [ ]	Unhappy [ ]	Very Unhappy [ ]

Q36	If Not happy, what are your main concerns?	**Q37a**	**Farming systems** What system of farming do you practice? Mono-cropping [ ] (Go to Section 2)

			Mixed cropping [ ] Mixed farming [ ]
		Q37b	What component of the farming above do you practice? ………………………………………….. Why?... ....

SECTION 2: FARMER ENTERPRISE QUESTIONS:

- **T1 – 9: Q38. Tree crops for use or market**

T1	**Tree Crop** **(if no Tree Crop go to Q 39)** What is the size of your crop 3 production plot? *(tick appropriate response)*	Less than $10m^2$			
		$10m^2$ $20m^2$ (4m x 4m)			
		$20m^2$ to $50m^2$ (up to 6m x 6m)			
		$50m^2$ to $100m^2$ (up to 10m x 10m)			
		$100m^2$ to $400m^2$ (up to 20m x 20m)			
		Larger – state size			
T2	How long have you been involved in commercial tree crop production and marketing?	Less than 1 Year		3 – 4 Years	
		1 – 2 Years		4 – 5 Years	
		2 – 3 Years		More than 5 Years	
T3	Surplus tree crops, a) Do you store tree crops b) Do you take them to market c) Do you compost or feed to animals	No [ ] (Go to T7) Yes [ ] if yes, type of store ………………….. No [ ] Yes [ ] if yes, which market ……………… No [ ] Yes [ ] if yes, Compost [ ] Animals [ ]			
T4	How far is this market from your production plot?	Less than 2 KMs		20 – 40kms	
		2 - 10 KMs		40 – 50kms	
		10 - 20 KMs		More than 50KMs	
T5	How long does it take you to get to this target market?	Less than 1 hour		3 – 4 hours	
		1 - 2 Hours		4 – 5 hours	
		2 – 3 Hours		More than 5 Hours	

T6	How do you get your produce to this target market?	Walk		Bicycle	
		Bus		Car	
		Other (specify)…….			
T7	How often do you supply tree crops to the market?	Daily			
		Weekly			
		Every 2 weeks			
		Once a month			
		Once a year			
T8	How long have you been supplying tree crops to the Market?	Less than 1 Year		3 – 4 Years	
		1 – 2 Years		4 – 5 Years	
		1 - 2 Hours		4 – 5 hours	
		2 – 3 Hours		More than 5 Hours	
T9	What is the quantity of input used on this enterprise?	Seeds [kg/plot] Fertilizers [kg/plot] Pesticides [litres/plot]			

Q39. Vegetables

V1-12

V1	**Vegetable** **(if no Vegetable go to Q 40)** What is the size of your Vegetable production plot? *(tick appropriate response)*	Less than $10m^2$			
		$10m^2$ $20m^2$ (4m x 4m)			
		$20m^2$ to $50m^2$ (up to 6m x 6m)			
		$50m^2$ to $100m^2$ (up to 10m x 10m)			
		$100m^2$ to $400m^2$ (up to 20m x 20m)			
		Larger – state size			
V2	Do you grow Vegetable for sale or home use at your farm?	YES for sale	No for home use (Go to V11)	Some for sale %	
V3	For how long have you been involved in commercial Vegetable production and marketing?	Less than 1 Year		3 – 4 Years	
		1 – 2 Years		4 – 5 Years	
		2 – 3 Years		More than 5 Years	
V4	Surplus Vegetable, a) Do you store vegetable	No [ ] Yes [ ] if yes, type of store …………………..			

	b) Do you take them to market c) Do you compost or feed to animals	No [ ] Yes [ ] if yes, which market ……………… No [ ] Yes [ ] if yes, Compost [ ] Animals [ ]			
V5	How far is this market from your production plot?	Less than 2 KMs		20 – 40kms	
		2 - 10 KMs		40 – 50kms	
		10 - 20 KMs		More than 50KMs	
V6	How long does it take you to get to this target market?	Less than 1 hour		3 – 4 hours	
		1 - 2 Hours		4 – 5 hours	
		2 – 3 Hours		More than 5 Hours	
V7	How do you get your produce to this target market?	Walk		Bicycle	
		Bus		Car	
		Other (specify)…….			
V8	How often do you supply Vegetable to the market?	Daily			
		Weekly			
		Every 2 weeks			
		Once a month			
V9	How long have you been supplying Vegetable to the Market?	Less than 1 Year		3 – 4 Years	
		1 – 2 Years		4 – 5 Years	
V10	How long does it take you to get your produce from your farm to the Market?	Less than 1 hour		3 – 4 hours	
		1 - 2 Hours		4 – 5 hours	
		2 – 3 Hours		More than 5 Hours	
V11	What is the quantity of input used on this enterprise?	Seeds [kg/plot] Fertilizers [kg/plot] Pesticides [ltrs/plot] Seedlings [units/polt]			
V12	Do you use manure?	No [ ] Yes [ ] if yes, do you treat before use? No [ ] Yes [ ]			

FIELD CROPS:

P1-9: Q40-44. Crop 1-5 (Where applicable).

P1		Less than $10m^2$	

	Crop 1 **(if no Crop 1 go to Q45)** What is the size of your crop 1 production plot? *(tick appropriate response)*	10m² 20m² (4m x 4m)			
		20m² to 50m² (up to 6m x 6m)			
		50m² to 100m² (up to 10m x 10m)			
		100m² to 400m² (up to 20m x 20m)			
		Larger – state size			
P2	How long have you been involved in commercial crop 1 production and marketing?	Less than 1 Year		3 – 4 Years	
		1 – 2 Years		4 – 5 Years	
		2 – 3 Years		More than 5 Years	
P3	Surplus crop 1, a) Do you store crop 1 b) Do you take them to market c) Do you compost or feed to animals	No [ ] (Goto P7) Yes [ ] if yes, type of store ………………….. No [ ] Yes [ ] if yes, which market ……………… No [ ] Yes [ ] if yes, Compost [ ] Animals [ ]			
P4	How far is this market from your production plot?	Less than 2 KMs		20 – 40kms	
		2 - 10 KMs		40 – 50kms	
		10 - 20 KMs		More than 50KMs	
P5	How long does it take you to get to this target market?	Less than 1 hour		3 – 4 hours	
		1 - 2 Hours		4 – 5 hours	
		2 – 3 Hours		More than 5 Hours	
P6	How do you get your produce to this target market?	Walk		Bicycle	
		Bus		Car	
		Other (specify)…….			
P7	How often do you supply crop 1 to the market?	Daily			
		Weekly			
		Every 2 weeks			
		Once a month			
		Once a year			
P8	How long have you been supplying crop 1 to the Market?	Less than 1 Year		3 – 4 Years	
		1 – 2 Years		4 – 5 Years	
		1 - 2 Hours		4 – 5 hours	
		2 – 3 Hours		More than 5 Hours	
P9	What is the quantity of input used on this enterprise?	Seeds [kg/plot] Fertilizers [kg/plot] Pesticides [litres/plot]			

- **L1 – 9: Q45. Livestock to market:**

L1	**(if no Livestock go to Q 42)** What is the size of your livestock production plot? *(tick appropriate response)*	Less than $10m^2$			
		$10m^2$ $20m^2$ (4m x 4m)			
		$20m^2$ to $50m^2$ (up to 6m x 6m)			
		$50m^2$ to $100m^2$ (up to 10m x 10m)			
		$100m^2$ to $400m^2$ (up to 20m x 20m)			
		Larger – state size			
L2	Do you keep livestock for sale or home use at your farm?	YES for sale	No for home use	Some for sale %	
L3	Are you involved in commercial livestock production and marketing? YES [ ] NO [ ]. If yes, for how long?	Less than 1 Year		3 – 4 Years	
		1 – 2 Years		4 – 5 Years	
		2 – 3 Years		More than 5 Years	
L4	How far is this market from your production pen?	Less than 2 KMs		20 – 40kms	
		2 - 10 KMs		40 – 50kms	
		10 - 20 KMs		More than 50KMs	
L5	How do you get your livestock to this target market?	Walk		Bicycle	
		Bus		Car	
		Other (specify)…….			
L6	How long does it take you to get to this target market?	Less than 1 hour		3 – 4 hours	
		1 - 2 Hours		4 – 5 hours	
		2 – 3 Hours		More than 5 Hours	
L7	How often do you supply livestock to the market?	Daily			
		Weekly			
		Every 2 weeks			
		Once a month			
		Others (specify)			

SECTION 3: PERCEPTIONS ON CLIMATE CHANGE & ENVIRONMENTAL CHALLENGES AWARENESS

Q46. What are the perceptions of the type of climate change experienced in your area?

Climatic Factor	**Highly Aware**	**Aware**	**Fairly Aware**	**Not Aware**
Change in temperature/Hot				
Poor relative humidity/Dryness				
Change in sunshine intensity				
Change in pattern of rainfall				
Change in fertility of most soils				
Change in rate of erosion				
Drought				
Flooding				
Change in arable yield				
Pest & diseases				

Q47	How do you get information on weather and Changes in climate?(tick as many as appropriate)	Personal observation/research [ ] Radio [ ] Newspaper [ ] TV [ ] Internet [ ] Research Institutes [ ] Government Agencies [ ] NGO staff [ ] Extension Agents [ ] Family and Friends [ ] Other [ ]

Q48. **How readily accessible are these pieces of information and what is the source?**

Source of Information	Information Type	Readily Accessible	Seldom Accessible	Not Accessible	Others (Specify)
	Weather				
	Pest & diseases				
	others				

Q49. In what language is the climate information disseminated? ……………………………………….

Q50. How often do you access the information? a. Weekly [ ] b. Monthly [ ] c. Once in 3 months [ ] d. Once in 6 months [ ] e. Once in a year [ ]

Q51. Do you pay for the information? YES [ ] NO [ ] If yes, how much……………………………..

Q52. Are you satisfied with the information received?

Very Satisfied	Satisfied	Unsatisfied	Very unsatisfied

If unsatisfied, state reasons:

Q53. Is extension information able to address these concerns? YES [ ] NO [ ]. If no, why………......

Q54. In what way has climate change affected you personally? (Rank the following questions according to your perceptions).

Climatic Factor	**Strongly Agree**	**Agree**	**Strongly Disagree**	**Disagree**
Create discomfort at work				
Health hazards				
Reduce productivity				
Increased drought				
Poor fertility of soil				
Increased rate of erosion				
Longer period of heat stress				
Decrease in arable yield				
Outbreak of new diseases				
More wind storms leading to property destruction				
Fewer land & animal				
others (specify)				

Q55. In your own opinion, what are the cause(s) and effects of Environmental challenges in your community?

Causes	Extent of Damage (effects)			Please, give examples
	Great Damage	Little Damage	No Damage	
Soil erosion				
Leaching				
Desertification				
Drought				
Pest and diseases				
Population				

Poverty				
Climate change				
Others (specify)				

SECTION 4: AUTONOMOUS ADAPTATION STRATEGIES (RESPONSES TO THE ENVIRONMENTAL CHALLENGES)

Q56. Have you made any change in the kind of activity (practices) that you usually do on your farm as a result of the environmental challenge?

Please choose one option:

( ) Yes

( ) No

Q57. What are your current practices for adaptation on the following production component (Indicate if Indigenous [I] or Transferred [T])?

Agricultural Production Component	Current Practice(s) (Please tick as many as possible)	Impacts (is it working or not?)	If not working, why?
CROPLAND MANAGEMENT	Crop Types [ ] Cropping Systems [ ] Tillage Systems [ ]		
WATER MANAGEMENT	Use of Irrigation [ ] Bunds [ ] Mulch [ ] Terracing [ ] Agroforestry [ ]		
DEGRADED LANDS RESTORATION	Nutrient Application [ ] Re-Vegetation [ ] No Till [ ]		

SEED, CROP SELECTION & SEEDLINGS PRODUCTION	Planting/Sowing Dates [ ] Sowing Facility [ ] Sowing Depths [ ] Seed Requirements [ ] Seed Dressing [ ] Improved varieties [ ] Use of local varieties [ ]		
SOIL FERTILITY MANAGEMENT	Use of Manure [ ] Mulching [ ] Fertilizer [ ] Cover Cropping [ ] Intercropping [ ] Crop Rotation [ ]		

Q58. Have you made any changes in the crop (s) you grow?

Please choose one option:

( ) Yes. If yes what changes

( ) No.

Q59. Have you made any changes in the type of livestock you raise?

Please choose one option:

( ) Yes. If yes what changes

( ) No

Q60. Have you switched to any other income generating activities?

Please choose one option:

( ) Yes. If yes what changes

( ) No

Q61. Have you made any changes in your house/land?

Please choose one option:

( ) Yes. If yes what changes

( ) No

Q62. What other type of strategies do you have to cope with bad seasons?

Please choose all that apply to you

[ ] Diversify to other business

[ ] Early planting date

[ ] Integrate crop and livestock

[ ] Look for a temporary job

[ ] Migrate to another place

[ ] Other (specify)………………………………………………

Q63. How would you describe the technologies/adaptation measures? 1=Highly beneficial [ ] 2=Beneficial [ ] 3=Neutral [ ] 4=Detrimental [ ] 5=Others…………………………

Q64. What government interventions/adaptation measures to drylands farming have you benefitted from?

Q65. Are you happy to continue this research to the later stages? Yes [ ] No [ ]

Q66. Do you have any other comments relevant to this work?
………
………
………
………
………

Thank you very much.

b. Farmer action plan (Calendar)

Crop/plot________________________

Month/Week	**Activity and means of doing it/quantity of input used**			
	Pre-planting (clearing, tillage, input sourcing, mulching)	**Planting (sowing, weeding, fertilizer application)**	**Post planting (harvesting, storage & treatment)**	**Post-harvest**
April, 2016				
Week 1				
Week 2				
Week 3				
Week 4				
May, 2016				
Week 1				
Week 2				
Week 3				
Week 4				
June, 2016				
Week 1				
Week 2				
Week 3				
Week 4				
July, 2016				
Week 1				
Week 2				
Week 3				
Week 4				
August, 2016				
Week 1				
Week 2				
Week 3				
Week 4				
September, 2016				
Week 1				
Week 2				
Week 3				
Week 4				
October, 2016				
Week 1				
Week 2				
Week 3				
Week 4				
November, 2016				
Week 1				
Week 2				
Week 3				
Week 4				
December, 2016				

Week 1				
Week 2				

Meals from bio-intensive farms by women

Crop	**Number of meals (tally)**
Bean	
Tomato	
Cabbage	
Pepper	
Okra	
Maize	
Onions	
Spinach	

c. CHECKLIST FOR FOCUS GROUP DISCUSSIONS

Introduction

My name is Patrick Nugun Jellason, and I am a PhD student of Royal Agricultural University, Cirencester-Gloucestershire, United Kingdom. I am working on improving farming practices in your areas. The project advocates the use of scientifically verified good practices for water, soil fertility and pest management such as agroforestry, conservation practices, integrated pest, nutrient and soil fertility management as a means of adapting to environmental change and mitigating greenhouse gases. We hope to, together select best suitable practices for solving these problems in your locations to enable us advice on what to implement. Your individual contributions are valued and you are expected to participate actively in the discussions as key stakeholders in this community. All information provided shall be treated anonymously and with strict confidentiality.

FGD Guiding Questions

<u>FGD 1: Elderly farmers (35 and above).</u>

<u>FGD 2: Women (all age).</u>

<u>FGD 3: Youth (18-34) separately.</u>

1. **Good practices**: Which of the following practices do you employ on your farm? (show list of GAPs)
2. **Low rainfall management**: How do you cope with low rainfall problems? How about late onset? Why do you do what you do? Is it adequate enough? What methods do you think can best support your current practices? (show list of options & ask them to suggest more)
3. **Soil fertility management**: How do you rate your soil fertility? What practices do you do to improve the fertility? Is it adequate enough? Why do you do what you do? What methods do you think can best support your current practices?
4. **Vulnerability analysis**:
    a. **Exposure**: Are you affected by poor rainfall? How? Are you affected by high temperature? How?
    b. **Sensitivity**: is the effect on farm? Livestock? Household? Village?
    c. **Adaptive capacity**: What have you done to manage this exposure? What assets do you possess to help you manage the exposure? Do you think it was sufficient/effective? Could you have done better given any form of help to manage these problems? What do you think can be done? Who makes decisions for adaptation in your household?
5. **Knowledge of environmental challenge**:
    a. **Local**: What is your on-farm knowledge & experience of environmental challenge?
    b. **Global**: What do you know about Global climate change? What is your experience of it?

c. **Adaptive capacity**: Have you done anything purposely to manage impact of the environmental change?

6. **Training**: If training is required, what method of knowledge exchange do you think is appropriate? (show list)
7. **Survey results**:
   a. **Women**: Why is women participation in agriculture low? How can we make women to be more involved?
   b. **Vegetable**: Why is there no-little involvement in vegetable production?
   c. **Mulching**: Why is there no-low uptake of mulching?
   d. **Irrigation**: Why is there low irrigation in your community? How can we take advantage of available rain to get the best from it? Is roof top water harvesting something we can try?
   e. **Labour bought in**: Why do you buy more labour? ***Prompt:*** Do your children participate much in farm activities? If not why not? Where is the place of farming in the future of this community?
   f. **Household activities**: Who does what at home? Why?
   g. **Migration (*cin rani*):** Dry season circulation by younger members of households was observed by previous researchers of northern Nigerian drylands as an adaptation strategy to seasonality! What can you say about it and the experience now?
   h. **Soil degradation:** You said this was a major challenge. What do you mean by this? How did you come to identify this? What where the indicators you used?
8. What can you say about taking care of the environment while farming? If not/important, why?

d. **Focus Group Discussion attendance** **Date…………………Community…………………………………Class of Focus Group…………………………**

S/no.	**Name**	**Age**	**Highest education**	**Type of employment**	**Location**	**Farming system**

e. Interview Schedule

Introduction

- Thank farmer for participation in study so far and for agreeing to be interviewed
- State that the interview is for the purpose of PhD student research, so a completely independent piece of work
- Aim is to further understand current practices of farmers in Zango & Kofa in response to environmental challenges, their perceptions and understanding of these challenges, and why they would change or not change practices that will enhance adaptation to, and mitigation of climate change.
- It is not a question and answer session and there are no right or wrong answers as any opinion is valuable.
- The interview should last about an hour and five minutes and anything you say will be strictly confidential – your responses will remain anonymous
- Ask for permission to record interview.

You and your farm (10 minutes)

I'd first like to know a bit more about your farm (things not covered in the survey etc)...

- **Please could you tell me about your farm?**
    - Enterprises on the farm? Type of crops?
    - Size of the farm and total production of each crop?
    - How do you cultivate your land? Tractor, ox-plough, hoe?
    - How many 100kg bags per ha do you harvest?
    - Type & quantity of input used (fertilizer, herbicide, manure etc)?
    - Distance to market?
    - Price per 100 kg of each produce?
    - Do you have other sources of income? From where? Amount per year?
- **What is your role on the farm?**
    - How long have you been farming?
    - How many people work on the farm in total? Source of labour?
- **Food security?**
    - Do you produce food for home consumption or sale?
    - How many meals do you cook at home per day?
- **Farm livestock?**
    - Any livestock kept? Type?
    - Number?
    - System of keeping?
    - Source of feed/water?
    - Purpose of keeping?

Environmental change Experience (30 minutes)

I just want to ask you a number of questions to Understand how environmental change has affected you and your farm business in the past and perhaps more recently...

- **Very generally, can you talk me through any direct experiences you've had with low rainfall availability & late onset of rains in the past...**
  - Can you recall any specific events that are significant (month/year)?
    Prompts: poor harvest, pest infestation, disease infestation, loss of complete crops, loss of livestock
  - How do they compare with each other?
- **Very generally, can you talk me through any direct experiences you've had with high and fluctuating temperatures in the past...**
  - Can you recall any specific events that are significant (month/year)?
    Prompts: poor harvest, pest infestation, disease infestation, loss of complete crops, loss of livestock
  - How do they compare with each other?
- **Very generally, can you talk me through any direct experiences you've had with pests and diseases incidences in the past...**
  - Can you recall any specific events that are significant (month/year)?
    Prompts: poor harvest, pest infestation, disease infestation, loss of complete crops, loss of livestock
  - How do they compare with each other?

- **Could you identify the event in which you were most significantly affected?**

- **Thinking about that time specifically when you experienced the events above - was your farm/routine/practices affected? How? What happened?**
  - Land damaged (area)?
  - Buildings affected?
  - Loss of production (yield or whole crop loss)?
  - Loss of livestock – relocation/sell
  - Financial loss?
  - Other losses/impact?
  - How long lasting were the effects? How long was your land affected?

- **Do you have a view on what caused the environmental problem in question? (Refer to the event(s) that has just been discussed if necessary)**
  - Explore all factors – climate change, low rainfall, late onset of rainfall, degradation, high temperatures
  - Why?

- **Were you prepared for the environmental challenges?**
  - Was there any warning? (From where/who?)
  - Did you have a contingency plan at all? What did you do as a result?

    - Had you put anything in place which meant the environmental challenge caused less of an impact? Was there anything you could have done that would have reduced the impact on your farm business/household?

- **How did you initially react to the environmental challenge and its impact(s) on your farm?**
    - Could you talk me through your thoughts and initial actions
    - Move livestock/equipment, sell livestock, look for alternative source of income within community, moved out of community to look for alternative source of income, wait for rain to fall, anyone contacted (why)?

- **Have you changed anything at all due to your experience with environmental challenges?**
    - Have you learnt anything/feel more prepared?
    - Do you do anything differently that you didn't used to do in the past? (Why/why not?)
    - Would you do anything differently if you experienced environmental challenges more frequently (say every year)?

- **How effective have those actions been in reducing risk/impact from environmental challenges on your farm? (If too soon to tell, how confident are you?)**
    - How do you feel about the risk of poor and late onset of rain on your farm now?
    - How do you feel about the risk of increased temperature on your farm now?
    - How do you feel about the risk of pests and diseases infestation on your farm now?

- **Is there anything else that you would like to/plan to do to reduce the risk of the above environmental challenges on your farm? (Barriers)**
    - Knowledge/information/skills
    - Resource/materials/finances

Views on Climate Change (25 minutes)

I'd now like to ask you a few questions about climate change and how you feel about the issue... (Emphasize that I'm not testing them on their knowledge, just want to know how they feel and how concerned or unconcerned they are about it)

- **What's the first thing that comes to mind when someone says climate change to you?**

I'll just read out the UN definition of climate change for information:

> *"Climate change refers to a change in the average and/or the variability of the climate's properties, and that persists for an extended period, typically decades or*

longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity."

- **Have you seen any signs of climate change? Is climate change affecting your farm/land?**
  - Explore what those signs are
  - ***Probe:*** Poor rainfall, late onset of rains, high temperatures and pests and diseases infestation involved?

- **In your opinion, is there any relationship between climate change and Poor rainfall, late onset of rains, high temperatures and pests and diseases infestation (generally)?**
  - Have you always felt like that? (if not, what has changed?)

- *I'll just read out a short quotation from the (Nigerian Federal Ministry of Environment Climate Change Department, 2011):*

  "Climate trends and projections point to significant negative impacts on agricultural productivity, affecting the livelihoods of farming families and communities, and reducing domestic food security. These same climate trends and projections also point to negative impacts on our vital freshwater resources, including increases in both flooding and drought conditions (depending on the region). We can also expect impacts on our coastal systems, including increased risk of storm surge damage, inundation of low-lying areas and salt-water intrusion into freshwater systems, all due to sea level rise. Climate change will also put pressure on our fisheries, our forests, and on Nigeria's rich biodiversity."

- **Does climate change concern you? (refer to answer provided in the survey and see if anything has changed) and ask if there are any reasons why/why not.**
  - Does the content of the passage above concern you?
  - Is there anything specifically that would make you concerned/more concerned about climate change?

- **In your opinion, is climate change a natural process or do humans contribute to it? To what extent?**
  - Do farmers specifically contribute to climate change?
  - Why do you feel like that?

Views on the Response to Climate Change

Finally, I'd just like to ask you about whether you'd thought about making any changes on your farm practices in the face of potential climate changes and how you view the potentials of Good Agricultural Practices (GAPs) towards adaptation & mitigation...

According to the FAO (2003):

***GAPs** are the **application of recommendations and available knowledge** to address environmental, economic and social sustainability issues on-farm production and post-production processes resulting in safe and quality food and non-food agricultural products.*

- *GAPs that are climate friendly offer farmers an opportunity to be **resilient** while holding unto **agro-ecological principles***

***-Climate-smart agriculture on the other hand,** is an approach of **achieving short-and-long-term agricultural development priorities in the face of climate change** which also helps in achieving other development objectives under an enabling technical, policy and investment conditions (FAO 2013).*

Also the National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (*Nigerian Federal Ministry of Environment Climate Change Department, 2011) stated that:*

"To prepare for and reduce these negative impacts of climate change, adaptation is essential. The word "adaptation" refers to changes that reduce the harm caused by climate change – for instance, changes in agricultural practices, improvements in how we manage and use water, and diversification of livelihoods. Adaptation is usually a longer-term process combining new and old strategies and knowledge."

- **Were you aware of the GAPs and their GHG mitigation potentials?**

- **What do you think about these GAPs and suite of options? (read GAPs)**

- **It would be good to go through each of these actions to see how you feel about each of their suggestions – your view on their practicality, whether you'd considered any – why/why not?**
  - o Are you doing them already because of suggestions by your extension agent/neighbour?
  - o Is there anything that appeals more?
  - o Any other reason for doing each specific action already? (***Probe:*** Experience, advice etc)
  - - *Environmentally friendly? Sense of social responsibility?*
  - o Any reason for not undertaking any of the actions? (knowledge, resource, belief)
  - - *Impact on production?*
  - o Should farmers in general be expected to carry out actions like these? (Responsibility)

- **Generally, is there any preference between mitigation and adaptation to you? (reconfirm definitions)**

UNEP defines Climate Change Mitigation as: "*refers to efforts to reduce or prevent emission of greenhouse gases. Mitigation can mean using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behavior. It can be as complex as a plan for a new city, or as a simple as improvements to a cook stove design. Efforts underway around the world range from high-tech subway systems to bicycling paths and walkways. Protecting natural carbon sinks like forests and oceans, or creating new sinks through silviculture or green agriculture are also elements of mitigation.*"

  - In terms of practicality and effectiveness

- **Is there anything else you've like to have done or you'd like to do in the future to response to climate change?**
  - Why?
  - When?

- **Recap**
  - Experience of environmental challenges: you said…
  - Views on climate change: you said…
  - Views on responses to climate change: you said…

- **Is there anything else you'd like to comment on or say?**

Thank you for your time

f. Interview summary form

Interviewee: ____________________________________Date of Interview: ________________

Place: ____ Time of Interview: ________________

Duration of Interview: ____________

Where did the interview take place?

Was the venue suitable?

Does anything need to be changed for future interviews?

How easy was it to establish rapport? Were there any problems and how can this be improved for next time?

Did the interview schedule work well? Does it need to be altered or improved?

What were the main themes which arose in the interview?

Did any issue arise which need to be added to the interview schedule for the next time?

Is the interviewee willing to be contacted again? Have I promised or send any information or supply them with the results or a copy of the transcript?

g. Ethics Information Sheet

About this Research

Study into Farmers' practices and perception of environmental challenges in Zango and Kofa

Aim is to further understand current practices of farmers in Zango & Kofa in response to environmental challenges, their perceptions and understanding of these challenges, and why they would change or not change practices that will enhance adaption to, and mitigation of climate change.

The research is being undertaken by a Postgraduate student at the Royal Agricultural University as part of his PhD studies. The research requires collecting some information about you and your farm, your experiences with environmental challenges, and your practices and perceptions towards environmental change.

Confidentiality

All information collected as part of this research will be treated as strictly confidential, and your name and personal details that will identify you will not feature in any reports of research findings.

Your participation in the research is voluntary – and you are not obliged to answer any questions that you do not wish to answer.

If you have any further questions or concerns about the project, please contact the principal investigator, Patrick Nugun Jellason (Phone: +447501040466 or Email: nugunpatrick.jellason@student.rau.ac.uk)

Agreement

I have read and understood the information sheet for this project.

Name of respondent (printed) ____________________________________

Signature ____________________________ Date________________

h. Good Agricultural Practices Pre- & Post-Training Survey Questionnaire

General information

Age: ……………………………

Gender: ……………………….

Farming system practiced: ………………………………………..

Educational level: ………………………………………………………

Name: ………………………………………………………………………….

1. Are you happy with your current practices?
   a. Not very happy ☐
   b. Not happy ☐
   c. Cannot say ☐
   d. Happy ☐
   e. Very happy ☐
2. Are you happy with your current yields?
   a. Not very happy ☐
   b. Not happy ☐
   c. Cannot say ☐
   d. Happy ☐
   e. Very happy ☐
3. Are you confident about your ability to solve environmentally related farming problems?
   a. Not very confident ☐
   b. Not confident ☐
   c. Cannot say ☐
   d. Confident ☐
   e. Very confident ☐

4. Do you need any training to support your farming?
   a. Not very sure ☐
   b. Not sure ☐
   c. Cannot say ☐
   d. Sure ☐
   e. Very sure ☐
5. Do you feel confident about your ability to solve problems of water shortages & drought?
   a. Not very confident ☐
   b. Not confident ☐
   c. Cannot say ☐

☐

☐

d. Confident
e. Very confident

6. Do you feel confident about your ability to solve problems of poor soil fertility?
   a. Not very confident
   b. Not confident
   c. Cannot say
   d. Confident
   e. Very confident

7. Do you think women have a role in supporting the attainment of food security of northern Nigerian dryland households?
   a. Not very sure
   b. Not sure
   c. Cannot say
   d. Sure
   e. Very sure

8. What aspect of your farming system needs changing?
   a. Field preparation
   b. Tillage practices
   c. Weeding
   d. Input application
   e. Post-harvest practices

9. How many litres of herbicide do you use in total?

10. How many bags of fertilizers do you use now in total?

11. Type of fertilizer used?

12. How many bags do you harvest per year in total?

13. How much do you spend on labour for tillage?

14. How much do you spend on labour for weeding?

15. How much do you spend on labour for harvesting?

16. How many hours do you spend on field clearing?

17. How many hours do you spend on tillage practices?

18. How many hours do you spend on planting?

19. How many hours do you spend on weeding?

20. How many hours do you spend on harvesting?

All information received will be treated as strictly confidential. The data gathered for this study will be only published provided that your name or any information which might identify you is not published.

Thank you for your cooperation.

Appendix 5i

Name: **Community:** **Age:** **Gender:**

Action plan implementation survey/barriers for non-adoption

	Practice	Fully adopted	Partially adopted	Not adopted	Why adopted/not adopted
Conservation practices	Mulching/cover crop				
	No-till				
	Crop rotation				
	No burning of crop residue				
Bio-intensive gardenin	Water harvesting/small scale irrigation				

<table>
<tr><td rowspan="2"></td><td>Garden preparation</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Composting</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Other good practices</td><td>Intensive livestock keeping</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Appropriate fertilizer application (micro-dosing)</td><td></td><td></td><td></td><td></td></tr>
<tr><td>*Improved seeds given (what was your experience?), did you save some for next year?</td><td colspan="4"></td></tr>
<tr><td></td><td>To what extent do you feel you can help other farmers in the future based on what you have learnt?</td><td colspan="4"></td></tr>
</table>

	How valuable was the training?	
	How can the training be improved?	

Codes

Trade-off with animal feed	A
Expensive/ no capital/ credit (economic)	B
I have my old method (socio-cultural)	C
Lack of information (institutional)	D
Lack of input	E
lack of market	F
Insufficient labour	G
Lack of asset	H
Lack of land/Poor tenure	I
Lack of technology	J
Climatic events	K
Lack of trust in the process	L
others	M-Specify

Appendix 6

Delphi study of Good Agricultural (Agronomic) Practices (GAP's) for Resources Management, Greenhouse Gas mitigation & Dissemination methods in Tropical Drylands-Round 2

I am NUGUN PATRICK JELLASON a PhD student in the Royal Agricultural University, Cirencester-UK conducting a research into appropriate agricultural practices for small-scale farmers in the drylands of sub-Saharan Africa with specific reference to North West Nigeria. Part of this study is to validate the scientific principles behind published GAP's for dryland agriculture. Below you will see a list of GAP's selected as relevant to small-scale farmers in dryland agriculture in sub-Saharan Africa. Please indicate with an (X) in the box those that you consider most appropriate to be practiced by these farmers. Should you wish to justify your reasons, please add this in the comments box that best represent your opinion. The questionnaire has been tested and it takes 20 minutes to answer. For any clarification you can contact my Director of studies: Dr Richard Baines (Richard.Baines@rau.ac.uk).

No.	Statements	Strongly Disagree	Partially Disagree	Partiall y Agree	Strongly Agree	Comments where applicable
	GAP's Overview					
1	GAP's are sufficient for soil fertility management in tropical drylands					
2	GAP's are sufficient for degraded land restoration in tropical drylands					
3	GAP's are sufficient for low rainfall & drought management in tropical drylands					

4	GAP's are sufficient for pest and diseases management in tropical drylands					
5	Farmers already use GAP's needed for sustainable agriculture in drylands					
6	Farmers need further knowledge on GAP's in drylands					
	Training on GAP's uptake & out-scaling to other communities					
7	Farmers should be trained on GAP's in drylands sustainability					
8	Farmers local knowledge should be considered in the generation, piloting and out-scaling of GAP's (participatory)					
9	The best method of innovation uptake in smallholder agriculture in Developing countries is ….					
	-Training and farmer action plans					
	-Training and visits					
	-Farmer field schools					
	-Pilot (trial)demonstration plots					

	-Innovation platforms (see note)[12]					
	-Farmer to farmer knowledge exchange (lead farmers)					
	-Others (please specify)					
10	The following GAPs are important for soil fertility management in tropical drylands					
	-Green manure incorporation					
	-Intensive control livestock grazing (more livestock)					
	-Appropriate fertiliser application (rates, timing & types)					
	-Integrated plant nutrient management					
	-Agroforestry practices (selected tree species)					
	-Mixed cropping					
	-Others (please specify)					
11	The following are important practices for degraded land restoration in tropical drylands					

[12] Innovation platforms are places of learning that leads to practical implementation of fundamental innovation.

	-Re-vegetation(afforestation)					
	-Nutrient amendments					
	-Conservation agricultural practices					
	-Percolation ponds & contouring					
	-Others (Specify)					
12	The following are important practices for low rainfall & drought management in tropical drylands					
	-Small scale precision irrigation					
	-Mulching					
	-Earth bunds & tied ridges					
	-Conservation (minimum) tillage					
	-Rooftop water harvesting					
	-Water harvesting ponds					
	-Composting					
	-Zai technique (see note)[13]					

[13] Zai technique involves digging of pits (20-30 cm) long and deep and 90 cm apart for collecting water in the field for planting crops. It originally started in the dry areas of Burkina Faso.

	-Others (please specify)					
13	The following are important practices for pest and diseases management in tropical drylands					
	-Crop rotation					
	-Pest resistant crop varieties					
	-Integrated Pest Management					
	-Destruction of crop residue					
	-Crop diversification					
	-Others (please specify)					

14	**The following GAP's can result in greenhouse gas mitigation**	**Yes**	**No**	**Unsure**	**Comments where applicable**
	-Green manure incorporation				
	-Intensive control livestock grazing (more livestock)				
	-Appropriate fertiliser application				
	-Integrated plant nutrient management				
	-Agroforestry practices				
	-Re-vegetation				
	-Nutrient amendments				
	-Conservation agricultural practices				
	-Percolation ponds & contouring				

	-Small scale precision irrigation				
	-Mulching				
	-Earth bunds & tied ridges				
	-Conservation (minimum) tillage				
	-Rooftop water harvesting				
	-Water harvesting ponds				
	-Composting				
	-Zai technique				

16	**Are there any important GAP's we have missed out? Yes [ ] No [ ]. If yes? In your opinion what are the five (5) most important GAP's that farmers need to be trained on in tropical drylands management?**
i.	
ii.	
iii.	
iv.	
v.	

17	**What is your area of specialty (please tick where applicable)**	
a	-Agronomy	
b	-Soil Science	
c	-Plant Science	
d	-General Agriculture	

1 8	**I am currently working in: (please tick where applicable)**	
a	University/College	
b	Research Institution	
c	Government Department	
d	Private company/business	
e	Regulatory Institution	
f	Multinational organisation	
g	Others (please specify)	

e	-Biology	
f	-Environmental Science	
g	-Others (please specify)	

1 9	**I am interested to participate in this study (please tick where applicable)**	
a	Yes	
b	No	
c	Maybe (please contact me again)	

If you have trained farmers on GAP's in the past, what was your experience?

On completing this questionnaire, could you please suggest 2 other experts whom I may contact?

Name of Expert 1:

Email:

Name of Expert 2:

Email:

Additional comments

Thank you.

Appendix 6b

Delphi study of Good Agricultural Practices (GAPs) for Resources Management, Greenhouse Gas mitigation & Dissemination methods in Tropical Drylands of northern Nigeria-Round 3

The Good Agricultural Practices (GAPs) Participatory Training Manual for northern Nigerian drylands we propose to develop contains selected good practices that should support agricultural water conservation, pests and diseases management as well as soil fertility and degradation management. The manual will also display the potentials of the GAPs for enhanced production and greenhouse gas mitigation and the scientific evidence behind their use. Farmers will be given the opportunity through trial to choose which practices are adaptable to their current practices with the aim to fine tune what works well and what does not.

The study is carried out in two rural farming communities (Zango and Kofa) in North Western Nigeria. Zango is a dry arid farming community in Zango Local Government Area of Katsina state sharing borders with the Republic of Niger. It lies on latitude 13^{o} 03’ 19.0” N and longitude 8^{0} 29’ 17.2” E. Total annual rainfall is approximately 591 mm. Farmers in this community are involved mainly in animal husbandry and production of cereal and legume crops. Cereals farmed include: sorghum and pearl millet while legume crops include: cowpea, soybean and groundnuts.

The second community Kofa lies between the semi-arid and Sudan Savannah Agro-ecological zones of Nigeria in Bebeji local Government Area of Kano state in North Western Nigeria. It lies on latitude 9^{o} 41’14.6” N and longitude 7^{o} 41’12.4” E and enjoys annual rainfall average of 835 mm. Farmers keep livestock and produce cereal, legume crops and some vegetables. Cereals farmed include: maize, sorghum and millet while legume crops include: cowpea, soybean and groundnuts. Vegetables farmed include onions, tomato and garlic.

Below you will see a list of GAPs selected and modified based on the feedback from the first round of responses. Please indicate with an (X) in the box those that you consider most appropriate to be practiced by these farmers. Should you wish to justify your reasons, please add this in the comments box that best represent your opinion. The questionnaire has been tested and it takes 20 minutes to answer. For any clarification you can contact my Director of studies: Dr Richard Baines (Richard.Baines@rau.ac.uk).

No.	**Statements**	**Strongly Disagree**	**Partially Disagree**	**Partially Agree**	**Strongly Agree**	**Comments and where applicable**
		1	2	3	4	

1.0	**GAPs[14] Overview**					
1.1	Appropriate GAPs with other complimentary practices[15] when understood & properly applied are sufficient for soil fertility management in tropical drylands					
1.2	Appropriate GAPs with other complimentary practices when understood & properly applied are sufficient for degraded land restoration in tropical drylands					
1.3	Appropriate GAPs with other complimentary practices when understood & properly applied are sufficient for low rainfall situations & drought management in tropical drylands					
1.4	Appropriate GAPs with other complimentary practices when understood & properly applied are sufficient for pest and diseases control in tropical drylands					
1.5	Generally farmers in these areas already use GAPs needed for sustainable agriculture in tropical drylands					

[14] GAPs (Good Agricultural Practices) refer to recommendations and available knowledge applied to address environmental, economic and social sustainability concerns for on-farm production and post-production processes that results in safe and quality food and non-food agricultural products.

[15] Complimentary practices refer to good husbandry, timeliness of operations including re-vegetation, conservation agriculture e.t.c.

1.6	Farmers need further support to adopt targeted GAPs in drylands through training & extension					
2.0	**Training on GAPs uptake & out-scaling to other communities**					
		Strongly Disagree	**Partially Disagree**	**Partially Agree**	**Strongly Agree**	**Comments and where applicable**
2.1	Farmers should be trained on GAPs in drylands sustainability					
2.2	Farmers local knowledge & socio-economic conditions should be considered in the generation, piloting and out-scaling of GAPs (participatory GAPs adaptation)					
2.3	**Effective engagement of smallholders in up taking GAP adaptation requires a combination of two or more of the following approach (es) in Developing countries**					
2.3.1	-Training and farmer action plans					
2.3.2	-Training and visits					
2.3.3	-Farmer field schools					
2.3.4	-Pilot (trial)demonstration plots					
2.3.5	-Innovation platforms (see note)[16]					
2.3.6	-Farmer to farmer knowledge exchange (lead farmers)					
	-Use of large anchor (role model) farms					
2.3.7	-Others (please specify)					

[16] Innovation platforms are places of learning that leads to practical implementation of a fundamental innovation.

3.0	**Good Agricultural Practices (Drylands)**	**Strongly Disagree**	**Partially Disagree**	**Partially Agree**	**Strongly Agree**	**Comments where applicable**
3.1	For soil fertility management, the following GAPs with other complimentary practices are important in tropical drylands					
3.1.1	-Green manure incorporation					
3.1.2	-Sustainable Pastoralism					
3.1.3	-Appropriate fertiliser application (rates, timing & types)					
3.1.4	-Integrated plant nutrient management					
3.1.5	-Agroforestry practices (selected tree species)					
3.1.6	-Mixed cropping					
3.1.7	-Intercropping legumes with other crops					
3.1.8	-Use of cover crops					
3.1.9	-Others (please specify)					
3.2	For degraded land restoration, the following with other complimentary practices are important practices in tropical drylands					
3.2.1	-Re-vegetation(afforestation) using appropriate tree species under secured land rights					
3.2.2	-Organic nutrient amendments					
3.2.3	-Conservation agricultural practices					
3.2.4	-Percolation ponds & contouring					

3.2.5	-Farmer managed natural regeneration					
3.2.6	-Sustainable pastoralism					
3.2.7	-Others (Specify)					

	Good Agricultural Practices (Drylands)	**Strongly Disagree**	**Partially Disagree**	**Partially Agree**	**Strongly Agree**	**Comments where applicable**
3.3	For low rainfall & drought management the following with other complimentary practices are important practices in tropical drylands					
3.3.1	-Small scale precision irrigation					
3.3.2	-Mulching					
3.3.3	-Earth bunds & tied ridges					
3.3.4	-Conservation (minimum) tillage					
3.3.5	-Rooftop water harvesting					
3.3.6	-Water harvesting ponds					
3.3.7	-Composting					
3.3.8	-Zai technique (see note)[17]					
3.3.9	-Others (please specify)					

[17] Zai technique involves digging of pits (20-30 cm) long and deep and 90 cm apart for collecting water in the field for planting crops. It originally started in the dry areas of Burkina Faso.

3.4	For pest and diseases management the following with other complimentary practices are important practices in tropical drylands					
3.4.1	-Crop rotation					
3.4.2	-Pest resistant crop varieties					
3.4.3	-Integrated Pest Management					
3.4.4	-Destruction of diseased crop residue					
3.4.5	-Crop diversification					
3.4.6	-Use of environmentally friendly herbicides and pesticides					
3.4.7	-Others (please specify)					

	GAPs in dryland GHG Mitigation				
4.0	**The following GAPs can result in greenhouse gas mitigation in tropical drylands**	**Yes**	**No**	**Unsure**	**Comments where applicable**
4.1	-Green manure incorporation				
4.2	-Sustainable Pastoralism				
4.3	-Appropriate fertiliser application				
4.4	-Integrated plant nutrient management				
4.5	-Agroforestry practices				
4.6	-Intercropping legumes with other crops				
4.7	-Use of cover crops				
4.8	-Re-vegetation				
4.9	-Organic nutrient amendments				
4.10	-Conservation agricultural practices				

4.11	-Percolation ponds & contouring				
4.12	-Small scale precision irrigation				
4.13	-Mulching				
4.14	-Earth bunds & tied ridges				
4.15	-Conservation (minimum) tillage				
4.16	-Water harvesting ponds				
4.17	-Composting				
4.18	-Zai technique				

6.0	**Employment**	
	I am currently working in: (please tick where applicable)	
a	University/College	
b	Research Institution	
c	Government Department	
d	Private company/business	
e	Regulatory Institution	
f	Multinational organisation	
g	Others (please specify)	

5.0	**Your expertise**	
	What is your area of specialty (please tick where applicable)	
a	-Agronomy	
b	-Soil Science	
c	-Plant Science	
d	-General Agriculture	
e	-Biology	
f	-Environmental Science	
g	Others (please specify)	

7.0. What additional practices do you think we should add to help farmers build resilience into their farming system?

8.0. What are the strengths and weaknesses with this tool?	
Strengths	**Weaknesses**

9.0. Do you have any suggestions to improve this tool?
Please comment:

10.0. Additional comments

Should you wish to be informed about the research project's progress please indicate below:

Yes pleases [ ]

No thanks [ ]

Finally, do you have any suggestion of experts you are familiar with who could contribute to the development of the farmer engagement research project?

1.

2.

All information will be treated as strictly confidential. The data gathered for this study will only be used for publication provided that your name or information which might identify you or your organisation is not used. **Thank you for your time and kind cooperation.**

Appendix 7

Theory of Planned Behaviour Survey Questionnaire

Name……………………………………………………….

Community……………………………………Gender……………

Please select the answer that best represents your opinion

	No.	**Farm Adaptation behaviour**	1	2	3	4
Attitude towards behaviour	**1**	For me climate change adaptation is	Very Irrelevant	Irrelevant	Important	Very important
	2	Climate change adaptation on my farm is	Very Difficult	Impossible	Possible	Very Practical
	3	Adaptation to climate change for me is	Very Inconvenient	Inconvenient	Convenient	Very Convenient
Subjective norm	4	I feel under pressure from extension agents to integrate adaptation to climate change in my farming	Strongly disagree	Disagree	Agree	Strongly agree
	5	People whom I respect (e.g. community head) will disapprove if I do not integrate adaptation in my farming	Strongly disagree	Disagree	Agree	Strongly agree
	6	It is expected of me to integrate adaptation to climate change in my farming since others are doing it	Strongly disagree	Disagree	Agree	Strongly agree
Perceived behavioural control	**7**	If I wanted to, it is easy to integrate adaptation in my farming	Strongly disagree	Disagree	Agree	Strongly agree
	8	Not having enough resources makes it difficult to adapt to climate change	Strongly disagree	Disagree	Agree	Strongly agree
	9	Whether I integrate adaptation into my farming is entirely up to me	Strongly disagree	Disagree	Agree	Strongly agree
Intention	10	I intend to integrate adaptation in my farming	Very unlikely	Unlikely	Likely	Very likely

Appendix 8

ROYAL AGRICULTURAL UNIVERSITY, CIRENCESTER, GLOUCESTERSHIRE, UNITED KINGDOM

SCHOOL OF AGRICULTURE, FOOD & ENVIRONMENT (SAFE)

TOPIC: Environmental Challenges and Linkages to Small Scale farming in sub-Saharan African Drylands: Implications for Food Security

SURVEY GUIDE FOR EXTENSION AGENTS/RESEARCH

Dear respondent,

I am a Postgraduate student of the Royal Agricultural University, Cirencester, United Kingdom. The following questions have been designed for the purpose of exploring the **Effects of Environmental Challenges & Risk Management Strategies in the Drylands of Nigeria**. Your response will be collated with those of farmers and researchers as key inputs to achieve the goals of this study. Please, respond to the best of your ability and provide enough details to assist in making informed decisions. I assure you that your responses will be treated as confidential and used solely for the purposes of this study.

Thank you.

Nugun Patrick Jellason

Date completed…………………………………………………………………………..........................

SECTION A: PERSONAL PROFILE

1. State…………………………………………………………………

2. LGA ……………………..……………………………………………….

3. **Sex**: No. of Males [ ] No. of Females [ ]

4. **Age:** 1..... 2..... 3......4……5….. (years)

5. Name & address of Institution presently employed:

6. Position/Rank:

7. Qualification(s):

8. Specialization:

9. No of years on the job as an extension officer/researcher:

10. Extension Block Name …….…….………………………………………………………………..

11. Extension Cell Name…………………..…………………………………………………………………

12. No of farmers in your designated area …………………………………………………………………

13. Number of farmers contacted:

Age range	**Males**	**Females**
Less than 5 yrs		
5 - 10 years		
11 – 20 years		
21 – 30 Years		
31 – 40 Years		
41 – 50 Years		
Above 50 years		
Doesn't know		

SECTION B: INTERVIEW QUESTIONS-EXTENSION/RESEARCH SUPPORT

1. What is the main focus of your research/extension?

2. What are your key challenges for research/extension? E.g.

- Funding [ ]
- Time [ ]
- Workload [ ]
- Experience [ ]
- Training [ ]
- Others (specify) [ ]

3. What is your funding for research and extension (is it adequate, is it timely)?

4. Name any existing private/Non-Governmental Organization involved in research/extension in your areas of focus and what they are doing.

SECTION C: FARMER/ENGAGEMENT

4a. In your view, what is the ratio of extension agents to farmers? ....

4b. What in your view would be the ideal ratio?

5. What sort of advice do you give farmers on enhancing efficiency of resource use in the drylands?

Soil	Water	Crop	Livestock

6. How do you engage with the farmers specifically around environmental constraints?

SECTION D: PROJECT/CHALLENGES

7. Are there any particular sustainable farming practices you are researching on to support farmers in the drylands? Yes [ ] No [ ]

8. If yes, what are you doing?

9. What is the progress of the project?

10. What are the challenges being faced with the project?

11. In your opinion, what do you think can be done to improve the challenges faced with the project?

12. In your view, in terms of environmental damage to farms; what do you think are the 3 most important areas that need addressing in terms of specific damages? (Rank 1-3 in terms of importance; 3=Most important, 2= Moderately important, 1= Least important).

i. Drought [ ]

ii. Desertification [ ]

iii. Pest & diseases [ ]

iv. Soil degradation [ ]

v. Others [ ] (specify) …………………………

SECTION E: GOOD AGRICULTURAL (AGRONOMIC) PRACTICES/TRAINING

13. Have you extended any Good Agricultural (agronomic) Practices to your clients related to drylands? Yes [ ]. No. [ ] If yes, which of the aspects and what practices did you advocate?

Agricultural Production Component	Current Practice(s) (Please tick as many as possible)	Impacts (is it working or not?)	If not working, why?
CROPLAND MANAGEMENT	Crop Types [ ] Cropping Systems [ ] Tillage Systems [ ]		
WATER MANAGEMENT	Use of Irrigation [ ] Bunds [ ] Mulch [ ] Terracing [ ] Agroforestry [ ]		
DEGRADED LANDS RESTORATION	Nutrient Application [ ] Re-Vegetation [ ] No Till [ ]		
SEED, CROP SELECTION & SEEDLINGS PRODUCTION	Planting/Sowing Dates [ ] Sowing Facility [ ] Sowing Depths [ ] Seed Requirements [ ]		

SOIL FERTILITY MANAGEMENT	Use of Manure [ ] Mulching [ ] Fertilizer [ ] Cover Cropping [ ] Intercropping [ ] Crop Rotation [ ]		

14. List any conferences/meetings/workshops/discussions on Good Agricultural (agronomic) Practices that you have participated in:

………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
....
………………………………………………………………………………………………………
………………………………………………………………………………………………………
……

15. List the conferences/meetings/workshops/discussions on drylands farming that you have participated in:

………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………
....
………………………………………………………………………………………………………
………………………………………………………………………………………………………
……

16. What training/conferences do you think you need?

17. Do you have any other comments relevant to this study?

Thank you very much.